Preliminary Final Rpt.
9/6 - Final to Come

NGT-21-002-080
NGT-80001

NASA/USRA

UNIVERSITY ADVANCED SPACE DESIGN PROGRAM

PRAIRIE VIEW A&M UNIVERSITY

PHASE II - TASK 1-B

INTEGRATED WATER SYSTEM FOR A SPACE COLONY

DESIGN OF A SURFACE—BASED FACTORY FOR THE PRODUCTION OF LIFE—SUPPORT AND TECHNOLOGY—SUPPORT PRODUCTS

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
PRAIRIE VIEW, TEXAS

JUNE, 1988

(NASA-CR-184730) DESIGN OF A SURFACE-BASED FACTORY FOR THE PRODUCTION OF LIFE SUPPORT AND TECHNOLOGY SUPPORT PRODUCTS. PHASE 2: INTEGRATED WATER SYSTEM FOR A SPACE COLONY Preliminary Final (Prairie View Agricultural

N89-19808

Unclas
G3/54 0189649

TABLE OF CONTENTS

<u>SECTIONS</u>

NASA/USRA - ADVANCED DESIGN PROGRAM CONCEPTUAL DESIGN OF AN INTEGRATED WATER SYSTEM FOR A SPACE COLONY.

PROJECT ADVISOR: Dr. K. Fotouh, P.E.

DEVELOPED BY STUDENTS

Adolphus Anderson	Ch.E.
Frank Woodson	Ch.E.
Brian Walker	C.E.
Angela Webb	E.E.
Danette Willis	Ch.E.
Harvey Williams	Arch.
Auby Legall Jr.	Ch.E.
Stanley Madumere	Ch.E.
Quintin Parker	Ch.E.

PRESENTED BY STUDENTS

Danette Willis	Ch.E.
Harvey Williams	Arch.
Charles Bisong	Ch.E.
Auby Legall Jr.	Ch.E.
Quintin Parker	Ch.E.
Ali Warsame	E.E.
Addie Branch	Ch.E.
Henry Efamba	Ch.E.

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

NASA/USRA

UNIVERSITY ADVANCED SPACE DESIGN PROGRAM

PRAIRIE VIEW A&M UNIVERSITY

TASK

DESIGN OF A SURFACE—BASED FACTORY
FOR THE PRODUCTION
OF
LIFE—SUPPORT
AND
TECHNOLOGY—SUPPORT
PRODUCTS

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
PRAIRIE VIEW, TEXAS

PHASE I: SURVIVAL

TASK I: PRODUCTION AND PURIFICATION OF WATER AND MANUFACTURING OF BREATHABLE AIR

TASK II: PRODUCTION OF PROTEINS AND FARMING

—

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
PRAIRIE VIEW, TEXAS

PVAM	NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

PHASE II: SELF—SUFFICIENCY

TASK I: MFG. OF FUELS, CHEMICALS, AGRICHEMICALS, PAINTS AND PHARMACEUTICALS (CARBON—BASED INDUSTRY)

TASK II: MFG. OF FERROUS AND NON—FERROUS METALS AND ALLOYS, AND POLYMERIC MATERIALS

TASK III: FABRICATION AND MACHINING OF STRUCTURES, ENGINES, AND EQUIPMENT

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
PRAIRIE VIEW, TEXAS

PHASE III:
PRODUCTION AND EXPORT TO EARTH
(MATERIALS AND TECHNOLOGY)

TASK I: REVIEW OF TECHNOLOGY

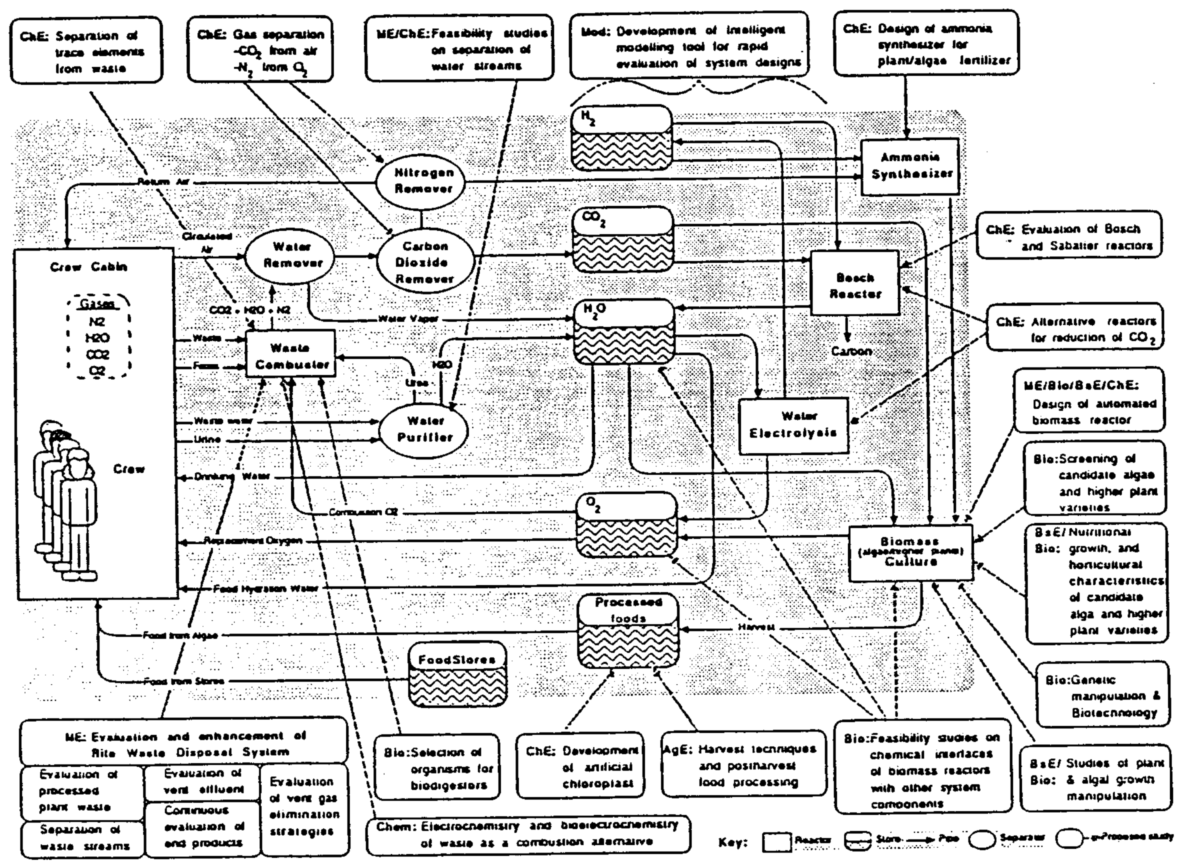
TASK II: MFG. OF ENZYMES AND HORMONES

TASK III: MFG. OF CRYSTALS

TASK IV: MFG. OF RADIATION RESISTANT MATERIALS

TASK V: OPEN FORUM

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
PRAIRIE VIEW, TEXAS



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

PRAIRIE VIEW A&M UNIVERSITY
COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
NASA/USRA - ADVANCED DESIGN PROGRAM
PHASE II - TASK 1B

CONCEPTUAL DESIGN OF AN INTEGRATED WATER TREATMENT SYSTEM TO SUPPORT A SPACE COLONY

SUMMARY:

In Phase II - Task 1A the Prairie View A&M University team completed the conceptual design of; a breathable air manufacturing system, a means of drilling for underground water, and storage of water for future use. The design objective of the team for the 1987-88 academic year (Phase II - Task 1B), has been the conceptual design of an integrated system for the supply of quality water for biological consumption, farming, residential and industrial use. The source of water for these applications is assumed to be artesian or subsurface.

The first step of the project was to establish the design criteria and major assumptions. Among these, we have included:

1. Water is scarce, therefore efficient water management through maximum recovery and reuse is critical.

2. Pollution problems will be minimized by exercising strict control on water discharge.

3. An effective hierarchial monitoring and control system will provide for quality control, and prompt attention to faulty equipment and leaks.

4. Since the pressure of the Martian atmosphere is only a small fraction of the earth atmosphere, all vessels and equipment must be sealed to prevent evaporation.

5. Three classes of water are defined: a. Water for farming must have a maximum mineral content such that plant life will flourish. b. Water for drinking must be free of pathogenic organisms and have a maximum salt content of less than 200 ppm. c. Water for manufacturing must be sufficiently free of ions such that they will not interfere with the manufacturing process or damage the quality of the product. d. Ion-free water will be provided for use in boilers in order to avoid erosion or corrosion of the materials of construction.

6. The various impurities which may be found in water and are reduced or removed at successive stages of treatment are:

turbidity, color, hardness, alkalinity, free mineral acid, carbon dioxide, pH, silica, oil, oxygen, hydrogen sulfide, ammonia, dissolved solids, suspended solids, organic solids, micro-organisms, and sulfate, chloride, nitrate, flouride, iron and manganese ions.

7. It has been assumed that the potential underground raw water supply resembles in quality from representative sources of underground water in Texas.

The assumed water impurities are:

	meq/l	ppm
Sodium Chloride {$NaCl$}	7.80	456.3
Magnesium Chloride {$MgCl_2$}	0.60	28.6
Magnesium Bi-Carbonate {$Mg(HCO_3)_2$}	0.36	43.9
Calcium Bi-Carbonate {$Ca(HCO_3)_2$}	0.57	46.2
Calcium Sulfate {$CaSO_4$}	3.07	208.0

8. Advanced technologies, which are not widely applied on earth, rather than traditional biological treatment, softening, and clarification techniques should be sought.

The second step of the effort was to generate a general block diagram of the expected treatment system and assign tasks to individual students. Among the treatment steps considered are:

sedimentation, softening, sand filtration, disinfection, ultrafiltration, reverse osmosis, demineralization, electrodialysis, vapor-compression evaporation, domestic waste treatment, and industrial waste handling.

At this early phase of study, no specific industries were selected, and hence no specific waste facilities were designed. It appears appropriate at this point in time to assume that evaporation by depressurization is a feasible means of recovering a major portion of the industrial waste water.

The list of processes for water purification and wastewater treatment given above suggests that there will be a need for on-site Chemicals manufacturing for ion-exchange regeneration, and disinfection.

The third step of the project was to set up a basis for the design capacity of the system. A total need of 10,000 gal/day was assumed required. It was also assumed that 30,000 raw-water intake volume is needed to produce the desired effluent volume. The following is a summary of the potential users and the level of treatment required:

APPLICATION	EFFLUENT
Farming	Municipal (domestic) wastewater treatment effluent. All waste produced by quarters and biological waste is directed to the waste water treatment facility. Additional water needed can be supplied by proper blending of reverse osmosis (stage 1) unit effluent and raw water to arrive to the desirable salinity level.
Domestic (Washing/Cooking)	The effluent from the reverse osmosis (stage 1) is disinfected and stored for use in the quarters.
Drinking	A part of the effluent from the reverse osmosis (stage 2) is disinfected and stored.
Processing (Manufacturing)	The major part of the reverse osmosis (stage 2) effluent is directed for this application.
Steam and Special Users	Ion-free deaerated water is produced for applications that require high purity water.

The fourth step of the project was for every individual student to screen the technology available and select the most suitable process(es) for his treatment phase. Detailed assumptions and criteria were established for each individual unit. As a result of these screening studies, the following sequence of treatment steps are selected for the system:

Sand Filtration: The purpose is to remove suspended solids with particle sizes of 10 microns and above. The process selected is a sand on gravel bed constructed on site. This has been chosen over cloth filtration and rotary vacuum filtration. The former is excluded because of the semi-manual nature of operation, the latter was excluded because of the moving parts and frequent need for maintenance. Figure 1 shows a guide for solid removal process selection.

Ultrafiltration: The process was selected as an additional cleaning step, for the removal of fine suspended solids; over microfiltration, centrifugation, and ultracentrifugation. Ultrafiltration was selected because it has a high removal efficiency for a wide range of particle sizes and has less moving parts. Size range of removal is 0.01 to 10 microns.

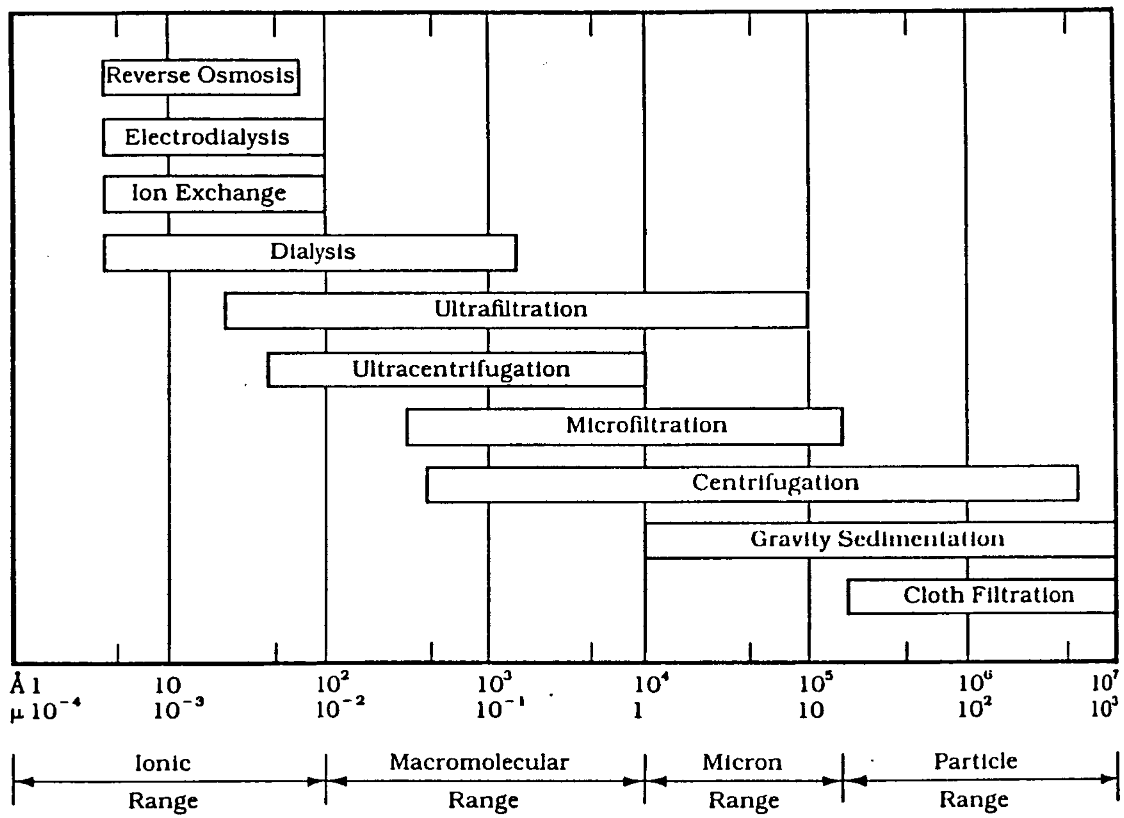
Reverse Osmosis: The process operation is based on increasing the pressure above the osmotic pressure of the brine solution to force clear water molecules across a permeable membrane. Two stages of reverse osmosis were preferred over one stage, each has a different membrane permeability. The first stage effluent can be used, in part, for domestic and farming applications. The remaining part of the first stage effluent is directed to the second stage osmosis process to produce extra clean water for industrial processing. The process was selected over electrodialysis for the lower power requirements, and over the ion exchange process for the size and weight.

Demineralization: This is an ion exchange process, and is being selected as a topping cleaning step to produce an ultra ion-free water for speciality manufacturing and steam making. The unit will be of much smaller size due to the fact that only a small part of the volumetric flowrate going through the second stage of the reverse osmosis unit will be demineralized.

Domestic Wastewater Treatment: The technology available is divided into two types based on cost only. The diversity of processes to select from is exemplified in Figure 2. Industrial wastewater facilities were not addressed at this point due to lack of information about the nature of contaminants produced.

A general arrangement of the designed system is shown in Figure 3. The industrial portion is hypothetically drawn and boxed for future analysis. The names of investigators are also written on the corresponding unit of the system.

Figure 1 Effective Ranges of Some Separation Techniques
Adapted from "Membrane Separation Processes" by R. E. Lacey in *Chemical Engineering*, 4 September 1972.



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING	
ADVANCED DESIGN PROJECT	
APPROVED BY: K. FOTOUH	
PAGE:	

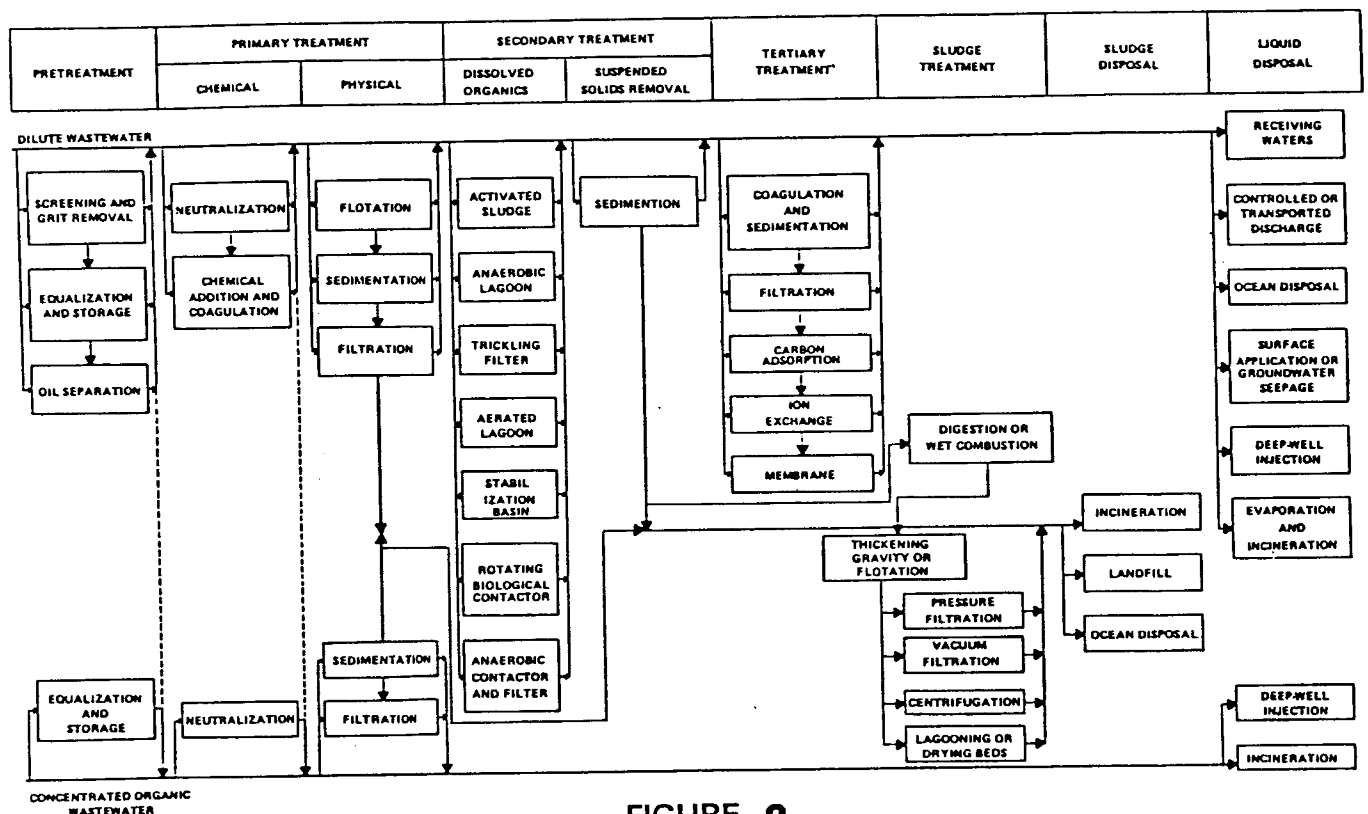


FIGURE 2
Wastewater Treatment Sequence—Processes Substitution Diagram

	NASA / USRA **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

1

SIMPLIFIED PLANT-WATER CIRCUIT

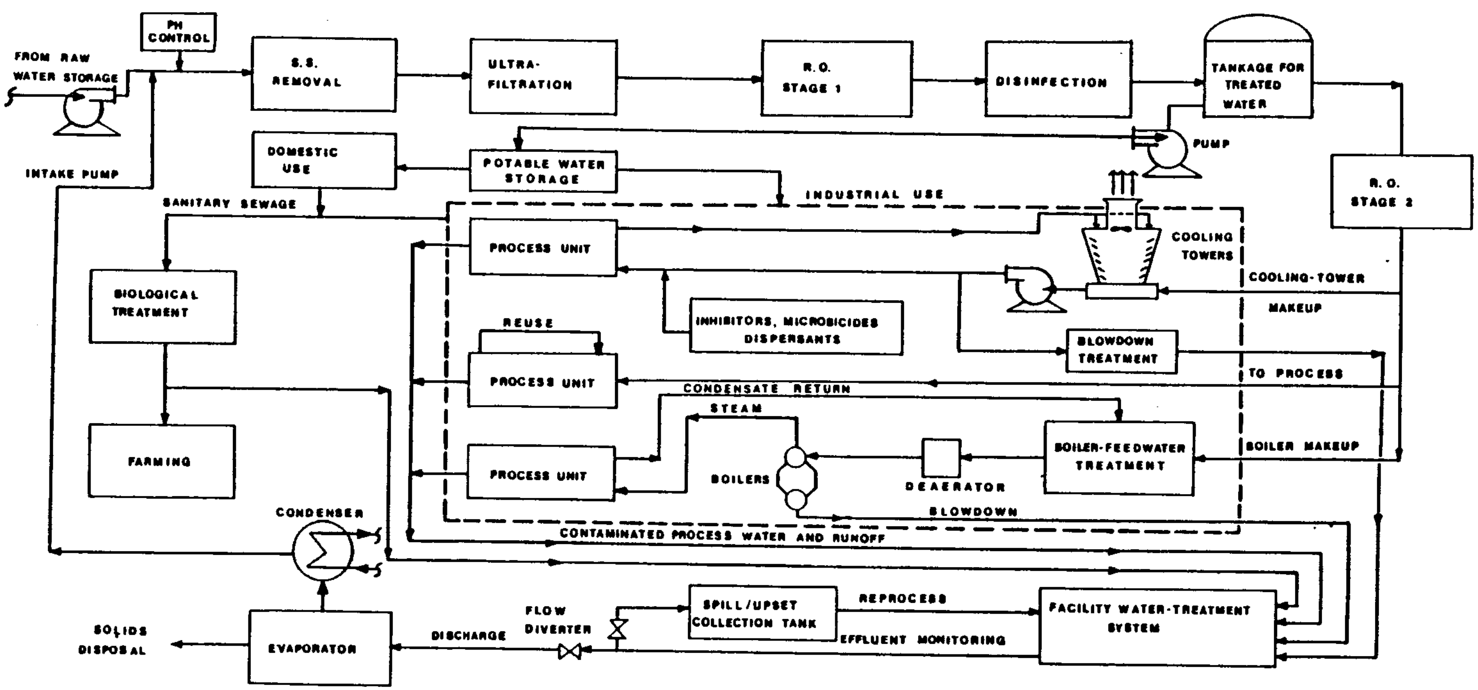


FIGURE 3

NASA/USRA

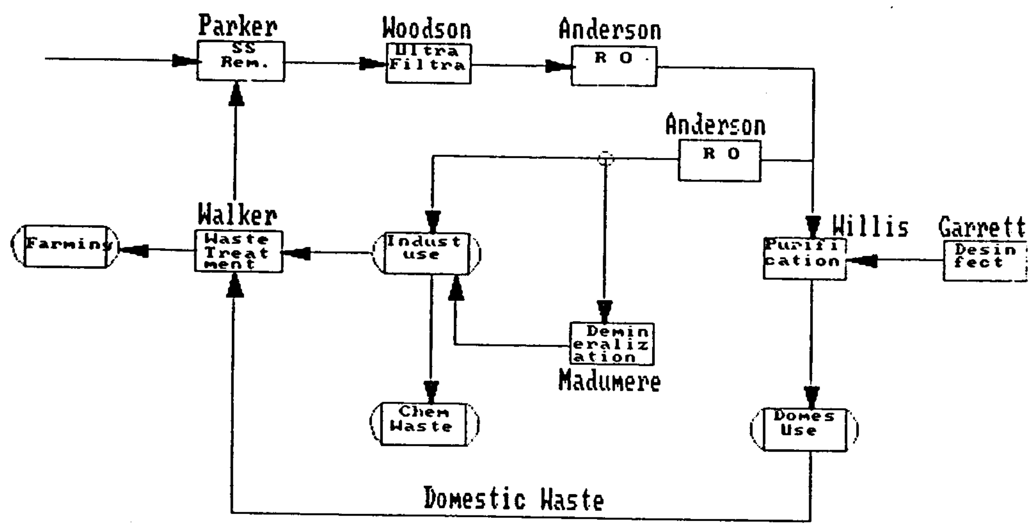
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

NASA/USRA ADVANCED DESIGN PROGRAM



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

OBJECTIVE: PRODUCE 10 000 GALLONS OF TREATED WATER PER DAY FROM AN INITIAL UNTREATED WATER SUPPLY EX THE DRILLING UNIT(S) AT 30 000 GALLONS PER DAY

BREAKDOWN OF TREATED WATER

DEMINERALIZED	1 000 GAL/DAY
PERSONAL CONSUMTION	1 000 GAL/DAY
MANUFACTURING	8 000 GAL/DAY

ASSUMED WATER COMPOSITION ON MARS

	meq/l	ppm
$NaCl$	7.80	456.3
$MgCl_2$	0.60	28.6
$Mg(HCO_3)_2$	0.36	43.9
$Ca(HCO_3)_2$	0.57	46.2
$CaSO_4$	3.07	208.8

CLASSIFICATION OF IMPURITIES

Suspended Solids	Organic
	Inorganic
Dissolved Solids	Organic
	Inorganic
Pathogenic Microrganisms	Aerobic
	Anaerobic

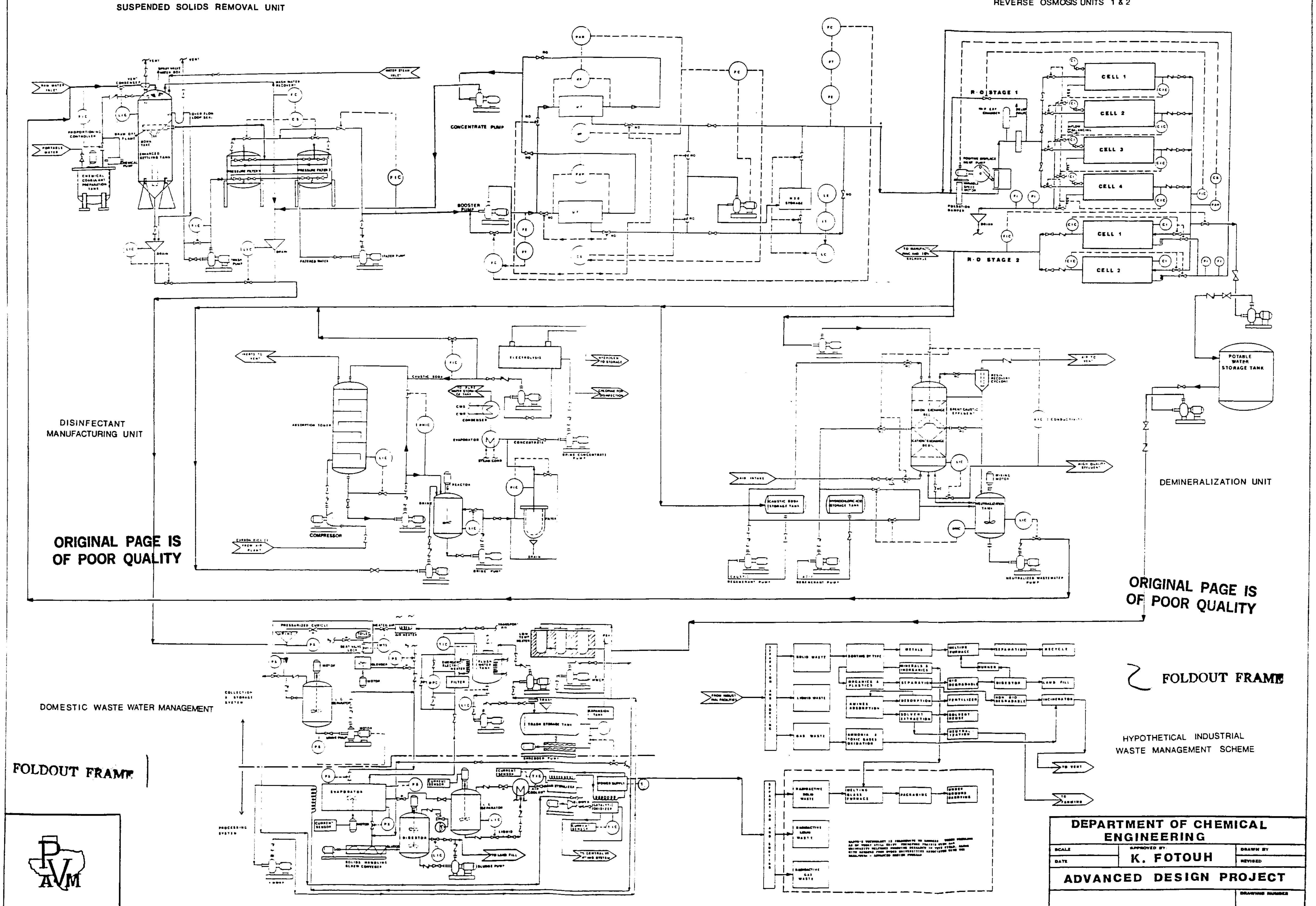
APPLICATION	QUALITY LIMITATIONS (TDS) PPM
Industrial	< 100
Drinking	< 300
Farming	< 2000

APPLICATION	EFFLUENT
Farming	Domestic Wastewater Treatment
Domestic (washing/cooking)	Reverse Osmosis (Stage 1)
Drinking	Reverse Osmosis (Stage 2)
Process (manufacturing)	Reverse Osmosis (Stage 2)
Steam and special uses	Ion Exchange Unit

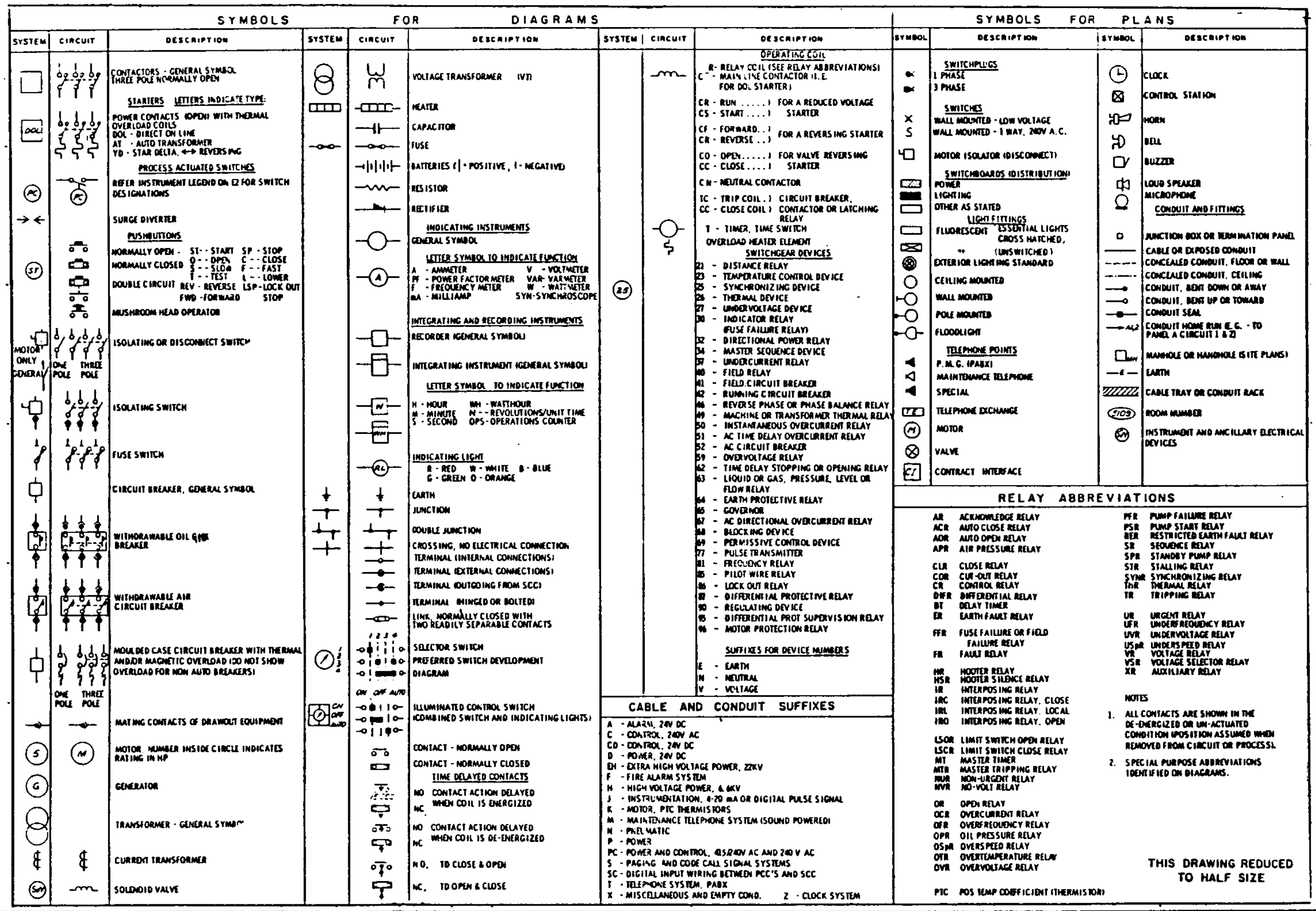
TREATMENT STEPS CONSIDERED

- Sedimentation
- Softening
- Sand Filtration
- Disinfection
- Ultrafiltration
- Reverse Osmosis
- Deminerilization
- Electrodialysis
- Vapor-Compression Evaporation
- Domestic Waste Treatment
- Industrial Waste Treatment

NASA/USRA - INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B



ORIGINAL PAGE IS
OF POOR QUALITY

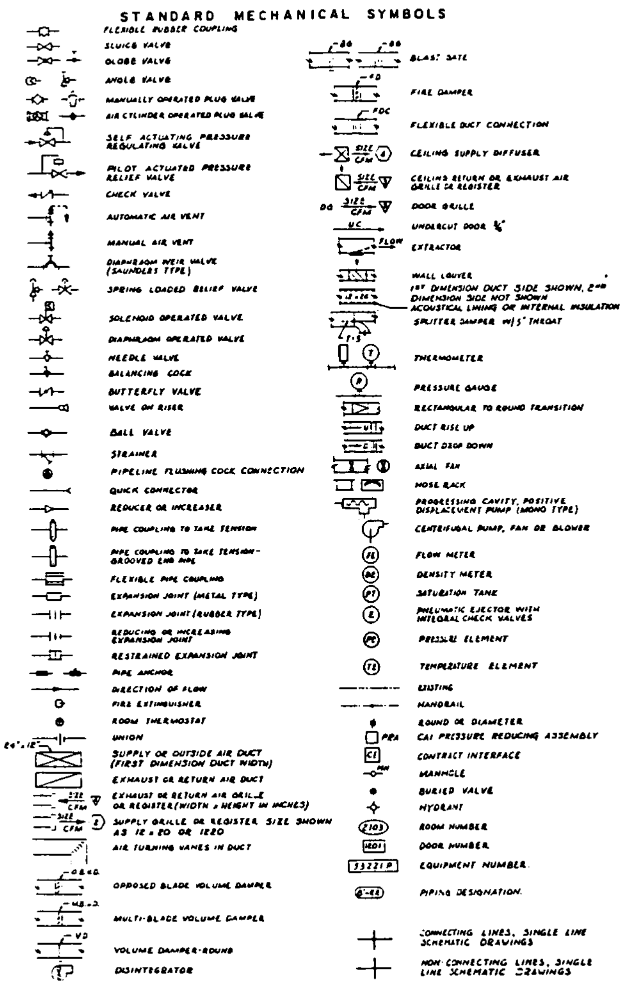


NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

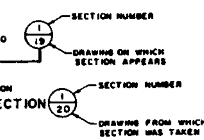
DEPARTMENT OF CHEMICAL ENGINEERING	
ADVANCED DESIGN PROJECT	
APPROVED BY:	K. FOTOUH
PAGE:	

STANDARD MECHANICAL SYMBOLS



ABBREVIATIONS

AC	AIR CONDITIONING
ADD	ADDITION (AL)
ADPT	ADAPTER
AFB	ANTI-FRICTION BEARING
ALUM	ALUMINIUM
AMB	AMBIENT
APPROX	APPROXIMATE
ATM	ATMOSPHERE
BF	BLIND FLANGE
BHP	BRAKE HORSEPOWER
BLO	BLOWER
BO	BLOW OFF
BOT	BOTTOM
BRZ	BRONZE
BTFLY VLV	BUTTERFLY VALVE
BTU	BRITISH THERMAL UNIT
BV	BALL VALVE
BYP	BY-PASS
C	CENTIGRADE
CAP	CAPACITY
CC	CENTER TO CENTER
CFM	CUBIC FEET PER MINUTE
CFS	CUBIC FEET PER SECOND
CH	CHAIN
CHAN	CHANNEL
CI	CAST IRON
CIP	CAST IRON PIPE
CIR	CIRCLE
CL	CHLORINE OR CLEARANCE
CLR	CLEAR
CO	CLEAN OUT
COLL	COLLECTOR
COMPR	COMPRESSOR
CREJ	CORRUGATED RUBBER EXPANSION JOINT
CS	CAST STEEL
CSK	COUNTERSINK
CSTG	CASTING
CU FT	CUBIC FOOT
CU IN	CUBIC INCH
CI	CONTRACT INTERFACE
CV	CHECK VALVE
CW	COLD WATER
DE	DENSITY METER
DET	DETAIL
DIA	DIAMETER
DIFF	DIFFERENTIAL
DO	DISSOLVED OXYGEN
DR	DRAIN
EA	EACH
ECC	ECCENTRIC
EL	ELEVATION
ELL	ELBOW
ENG	ENGINE
EXP JT	EXPANSION JOINT
F	FAHRENHEIT
FA	FRESH AIR
FB	FLAT BAR
FCO	CLEANOUT FLUSH WITH FINISHED FLOOR
FD	FLOOR DRAIN
FLG	FLANGE
FE	FLOW METER
FLR	FLOOR
FMH	FLEXIBLE METAL HOSE
FPC	FLEXIBLE PIPE COUPLING
FPC-1	FLEXIBLE PIPE COUPLING TO TAKE TENSION
FPM	FEET PER MINUTE
FPS	FEET PER SECOND
FRP	FIBERGLASS REINFORCED PLASTIC
FT	FOOT
FUT	FUTURE
GA	GAUGE OR GAGE
GALL	GALLERY
GALV	GALVANIZE
GD	GUARD
GEN	GENERATOR
GLV	GLOBE VALVE
GPM	GALLONS PER MINUTE
GRD	GROUND
GSKT	GASKET
HP	HIGH PRESSURE OR HORSEPOWER
HTR	HEATER
HV	HOSE VALVE
HW	HIGH WATER
HYD	HYDRAULIC
IN	INCH
INF	INFLUENT
INV	INVERT
INV EL	INVERT ELEVATION
LP	LOW PRESSURE
MACH	MACHINE
MAX	MAXIMUM
MGD	MILLION GALLONS PER DAY
MGL	MILLIGRAMS PER LITER
MH	MANHOLE
MI	MALLEABLE IRON
MIL GAL	MILLION GALLONS
MISC	MISCELLANEOUS
MV	MUD VALVE
NIC	NOT IN CONTRACT
NRS	NON-RISING STEM
NC	NORMALLY CLOSED
NO	NORMALLY OPEN
Ø	ROUND OR DIAMETER
OPNG	OPENING
P SL	PIPE SLEEVE
PG	PRESSURE GAGE
PL	PLATE
PNEU	PNEUMATIC
PRI	PRIMARY
PRV	PRESSURE REDUCING VALVE
PS	PRESSURE SWITCH
PSI	POUNDS PER SQUARE INCH
PSIA	POUNDS PER SQUARE INCH ABSOLUTE
PRA	AIR PRESSURE REDUCING ASSEMBLY
PSIG	POUNDS PER SQUARE INCH-GAUGE
PSF	POUNDS PER SQUARE FOOT
PV	PLUG VALVE OR PRESSURE REGULATING VALVE
QCPLG	QUICK COUPLING
RCP	REINFORCED CONCRETE PIPE
REQD	REQUIRED
RPM	REVOLUTIONS PER MINUTE
RV	RELIEF VALVE
RWP	RAINWATER PIPE
SCH	SCHEDULE
SD	SPLITTER DAMPER
SEC	SECONDARY
SEW	SEWER
SHT	SHEET
SIM	SIMILAR
SP	STATIC PRESSURE
SPEC	SPECIFICATION
SQ	SQUARE
SS	STAINLESS STEEL
SSK	SERVICE SINK
STD	STANDARD
SURF	SURFACE
SV	SAFETY VALVE
TYP	TYPICAL
V	VALVE
VAC	VACUUM
VB	VALVE BOX
VENT	VENTILATE
VTR	VENT THROUGH ROOF
WC	WATER COLUMN, WATER CLOSET
WCO	WALL CLEANOUT
WG	WASTE GAS
WI	WROUGHT IRON
WO	WITHOUT
WS	WATER SURFACE
WT	WATERTIGHT



(1) SECTION CUT ON DWG 20

(2) ON DWG 19 THIS SECTION IS IDENTIFIED AS:

(3) DETAILS ARE CROSS-REFERENCED IN A SIMILAR MANNER, EXCEPT THAT DETAILS ARE IDENTIFIED BY LETTER RATHER THAN BY NUMBER.

TYPICAL SECTION AND DETAIL NUMBERING SYSTEM

THIS DRAWING REDUCED TO HALF SIZE

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY

PIPING SYSTEMS ABBREVIATIONS AND CODE DESIGNATION

ABBR	SYSTEM	CODE DESIGNATION	ABBR	SYSTEM	CODE DESIGNATION
A	AERATION AIR	6	ML	MIXED LIQUOR	AS SPECIFIED
CAA	CHANNEL AERATION AIR	6	MSG	MEDIUM PRESSURE SLUDGE GAS	9
CAE	COMPRESSED AIR - ENGINE STARTING	15	NG	NATURAL GAS	25
CAI	COMPRESSED AIR - INSTRUMENTATION	4	PA	PREAERATION AIR	6
CAS	COMPRESSED AIR - SERVICE	4	PD	PUMPED DRAINAGE	7
CLG	CHLORINE GAS	10	PE	PRIMARY EFFLUENT	7
CLL	CHLORINE LIQUID	10	PS	PRIMARY SLUDGE	12
CLS	CHLORINE SOLUTION	21	PSC	PRIMARY SCUM	12
CLV	CHLORINE GAS VACUUM	23	RAS	RETURN ACTIVATED SLUDGE	7
CS	CIRCULATING SLUDGE	7	RWL	RAIN WATER LEADER	24
CWR	CHILLED WATER RETURN	16	SCF	STEAM CLEAN FLOW	11
CWS	CHILLED WATER SUPPLY	16	SCR	STEAM CLEAN RINSE	11
DIS	DISTILLED WATER	3	SAE	SAMPLE - EFFLUENT	7
DS	DIGESTED (NG) SLUDGE	7	SAI	SAMPLE - INFLUENT	7
EE	ENGINE EXHAUST	7	SAS	SAMPLE - SLUDGE	7
EI	ENGINE INTAKE	7	SAML	SAMPLE - MIXED LIQUOR	7
EJF	ENGINE JACKET WATER FLOW	5	SG	SCREENINGS	13
EJR	ENGINE JACKET WATER RETURN	5	SRA	SCUM REMOVAL AIR	20
EV	ENGINE CRANK CASE VENTILATION	8	SN	SUPERNATANT	7
FAE	FOUL AIR EXHAUST	23	SD	SANITARY DRAIN	18
FOR	FUEL OIL RETURN	5	SSC	SECONDARY SCUM	7
FOS	FUEL OIL SUPPLY	5	STD	STORM DRAIN	18
GR	GRIT	17	TD	TANK DRAIN	19
HRF( )	HEAT RESERVOIR FLOW (LOOP NUMBER)	16	TS	TRANSFER SLUDGE	7
HRR( )	HEAT RESERVOIR RETURN (LOOP NUMBER)	16	TO	WASTE SLUDGE THICKENER OVERFLOW	7
HOH	HIGH PRESSURE HYDRAULIC OIL	14	TWAS	THICKENED WASTE ACTIVATED SLUDGE	7
HOL	LOW PRESSURE HYDRAULIC OIL	14	TXO	TRANSFORMER OIL	8
HWR	DOMESTIC HOT WATER RETURN	5	VAC	VACUUM	4
HWS	DOMESTIC HOT WATER SUPPLY	5	V	VENT	2
HSG	HIGH PRESSURE SLUDGE GAS	9	WAS	WASTE ACTIVATED SLUDGE	7
LOC	CLEAN LUBE OIL	8	WHWR	WASTE HEAT COOLING WATER RETURN	16
LOD	DIRTY LUBE OIL	8	WHWS	WASTE HEAT COOLING WATER SUPPLY	16
LOR	LUBE OIL RETURN	8	1W	NUMBER 1 WATER	1
LOS	LUBE OIL SUPPLY	8	2W	NUMBER 2 WATER	1
LSG	LOW PRESSURE SLUDGE GAS	9	3W	NUMBER 3 WATER	1
DW	DEMINERALIZED WATER	21	3WL	LANDSCAPING IRRIGATION WATER	22
			3WS	FOAM SUPPRESSING SPRAY WATER	20
			RS	RECIRCULATED SLUDGE	7
			TBS	THICKENER BOTTOM SLUDGE	7

USE OF PIPING SCHEDULES

1. "PIPING SYSTEMS ABBREVIATIONS AND CODE DESIGNATION" TABLE INDICATES THE PIPING CODE DESIGNATION FOR EACH SYSTEM.
2. ENTER "PIPING SCHEDULE" TABLE WITH CODE DESIGNATION TO DETERMINE PIPE MATERIAL DESIGNATION.
3. ENTER "PIPING MATERIAL LIST" (DWG M3) WITH PIPE MATERIAL DESIGNATION FOR DETAILED PIPE MATERIAL SPECIFICATION.
4. PIPES ARE IDENTIFIED ON THE DRAWINGS AS FOLLOWS:

4" MSG (9)
CODE DESIGNATION
SYSTEM ABBREVIATION
PIPE DIAMETER

PIPING SCHEDULE

CODE DESIGNATION	SYSTEMS[k]	PIPE MATERIAL CLASSIFICATION			
		EXPOSED		BURIED, EMBEDDED OR ENCASED	
		2 INCHES AND SMALLER	2-1/2 INCHES AND LARGER	2 INCHES AND SMALLER	2-1/2 INCHES AND LARGER
1	1W, 2W, 3W	A-1	B-5[m], C-3[m]	A-2	C-2, B-10[b]
2	V	A-3	A-3, C-1	A-3, B-1	A-3, B-1
3	DIS	A-4	---	—	------
4	CAI, CAS, VAC	A-5	B-5	---	------
5	EJF, EJR, HWR, HWS, FOR, FOS	A-1	B-5	A-2	B-5[a]
6	A, CAA, PA	B-2	B-5, B-16[b]	B-2	B-5[a], C-3
7	CS, DS, EE, EI, PD, PE, RAS, RS, SAE, SAI, SAS, SAML, SN, SSC, TBS, TD, TS, TWAS, WAS	B-1	B-5[j]	B-1	B-5[a], C-3[m]
8	EV, LOC, LOD, LOR, LOS, TXO	B-2	B-5	B-7[a]	B-5[a], C-3[g]
9	LSG, MSG, HSG	B-2	B-15	B-2[a]	B-15[a]
10	CLG, CLL	B-3	---	B-3[a]	------
11	SCF, SCR	B-4	---	—	------
12	PS, PSC	---	B-6[e]	—	B-6[a,e]
13	SG	—	B-7	---	B-7[a]
14	HOH, HOL	B-8	---	B-8[a]	------
15	CAE	B-9	B-9	---	------
16	CWR, CWS, HRF, HRR, WHWR, WHWS	B-14	B-5	—	B-5
17	GR	---	B-13	—	B-13[a]
18	SD, STD	A-3[h]	C-1[c]	A-3[h]	C-1[c], C-3[c]
19	TD	B-2	B-5	—	C-3
20	SRA, 3WS	D-1	D-2	—	------
21	CLS, DW	D-2	D-2	D-2	D-2
22	3WL	---	---	D-3	D-3
23	CLV, FAE	E-1[d]	E-1[d]	E-1[d]	E-1[d]
24	RWL	---	C-1, B-2	—	C-1, B-2[a]
25	NG	D-2	B-15	B-2	B-15[a,i]

[a] PROTECTIVE WRAP ON BURIED LINES. A.S. A126, A127 AND CA36. TWO LAYERS OF FIBERGLASS REINFORCED COATING. THIS REQUIREMENT DOES NOT APPLY TO LINES REQUIRING INSULATION.

[b] SYSTEM B-16 IS FOR PIPES LARGER THAN 4 INCHES IN DIAMETER. FOR SMALLER PIPES, USE SYSTEM B-5.

[c] FOR SITE STORM DRAINAGE PIPING, SEE SPECIFICATIONS FOR MATERIALS.

[d] MANUFACTURER SHALL CERTIFY THAT PIPE AND INSTALLATION IS ACCEPTABLE FOR OPERATING CONDITIONS AND PROVIDE GUARANTEE FOR BURIED PIPES OUTSIDE OF STRUCTURES. SEE SPECIFICATIONS FOR MATERIALS.

[e] GLASS LINED PIPE NOT REQUIRED FROM SLUDGE HEAT EXCHANGERS TO DIGESTERS.

[f] ENGINE INTAKE AND LUBRICATING OIL PIPING AND FITTINGS SHALL BE SCHEDULE 40 AND PICKLED AFTER FABRICATION IN ACCORDANCE WITH A.S. CK 9.5.

[g] CAST IRON PIPE SHALL NOT BE USED FOR EE, EI, LOD, LOR, LOS, TXO.

[h] CAST IRON PIPE MAY BE USED FOR 2" DRAIN LINES FROM EQUIPMENT PADS IN LIEU OF COPPER PIPE.

[i] LAP WELDED SLIP JOINTS AND EPOXY LINING.

[k] SEE SPECIFICATIONS FOR INSULATION REQUIREMENTS.

[m] PIPE AND FITTINGS CEMENT MORTAR LINED IN ACCORDANCE WITH MMBW STD. SPEC. 64.A.199.

THIS DRAWING REDUCED
TO HALF SIZE

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY

INSTRUMENT LEGEND

	1ST LETTER AND SUCCEEDING LETTERS		
	MEASURED OR INITIAL VARIABLE	PASSIVE FUNCTION	OUTPUT FUNCTION
A			ALARM
Ae			ALARM OPERATING AN EMERGENCY DEVICE
C	CONDUCTIVITY		CONTROLLER
D	MULTIVARIABLE		
dL	DIFF'L LEVEL		
DO	DISSOLVED OXYGEN		
dP	DIFF'L PRESSURE		
E		ELEMENT	
F	FLOW		
G	SG OR DENSITY		
H			HAND CONTROL
I		INDICATOR	
K			COMPUTING RELAY
L	LEVEL HEIGHT		
M	MANUAL		
O	OXYGEN		
pH	H2 ION CONC		
P	PRESSURE		
Q	QUANTITY		
	ANALYSIS		
	CONCENTRATION		
R		RECORDER	
S		SUMMATOR OR INTEGRATOR	
Sp	SPEED		
T	TEMPERATURE		
Tu	TURBIDITY		
t	TIME		
U	DIMENSION		
	MECH MOVEMENT		
Vn	VIBRATION		
W	WEIGHT, MASS, LOAD		
X			TRANSMITTER
Z			MISCELLANEOUS

IDENTIFICATION SYMBOLS FOR ANCILLARY AND ASSOCIATED EQUIPMENT

BR	BOOSTER RELAY
BT	BUBBLER TUBE
D/A	DIGITAL TO ANALOG CONVERTER
DP/P	DIGITAL PULSE TO PNEUMATIC CONVERTER
I/P	CURRENT TO PRESSURE CONVERTER
mV/I	MILLIVOLT TO CURRENT CONVERTER
P/I	PRESSURE TO CURRENT CONVERTER
R/I	RESISTANCE TO CURRENT CONVERTER
SS	SELECTOR SWITCH
Td	TRANSDUCER
V/I	VOLTAGE TO CURRENT CONVERTER
Z	MISCELLANEOUS (ADD NOTE SPECIFYING FUNCTION)

SYMBOLS FOR COMPUTER SYSTEM SCHEDULES

$(MV)^{1/2}$	SQUARE ROOT EXTRACTION OF MEASURED VARIABLE
$\int MV$	INTEGRATION OF MEASURED VARIABLE
$\Sigma MV'S$	SUMMATION OF SPECIFIED MEASURED VARIABLES
P	PROPORTIONAL CONTROL
PI	PROPORTIONAL AND INTEGRAL CONTROL
PID	PROPORTIONAL, INTEGRAL AND DERIVATIVE CONTROL

SYMBOLS FOR INSTRUMENTS

GRAPHIC SYMBOL	IDENT'N	DESCRIPTION
		INSTRUMENT
		COMPLETE INSTRUMENT MOUNTED IN FLOW LINE
SYMBOLS FOR ANCILLARY ITEMS		
		DIAPHRAGM PRESSURE SEAL
		THERMOMETER WELL OR PIPE TAP
		EXTERNALLY MOUNTED TEMPERATURE SENSOR
	A	ELECTRIC ACTUATOR
	A	PNEUMATIC OR HYDRAULIC POWER CYLINDER
	A	POWER CYLINDER WITH POSITIONER
	ZE	WATER REACTION UNIT OR PURGE FLOW INDICATOR INCORPORATING NEEDLE VALVE.
	ZE	ROTAMETER WITH NEEDLE VALVE.
	FE	MOISTURE TRAP (AUTOMATIC DISCHARGE)
	Fr	AIR OR WATER FILTER
	ZE	COMBINED AIR FILTER AND WATER TRAP
	PIC	MANUALLY SET PRESSURE REGULATOR WITH GAUGE
BP	BP	BUBBLER PANEL
SYMBOLS FOR PRIMARY SENSING ELEMENTS		
	FE	ORIFICE PLATE AND IMPULSE LINES
	FE	VENTURI OR DALL TUBE
	FE	MAGNETIC FLOWMETER
FE	DE	DENSITY MEASURING ELEMENT
	FE	POSTIVE DISPLACEMENT METER
SYMBOLS FOR PLANT		
		PUMP
		MOTOR AND DRIVE SHAFT
		MOTOR WITH SPEED REGULATOR
TO ATMOS / TO DRAIN	ZE	SLUDGE SETTLING AND GAS COLLECTING CHAMBER

SYMBOLS FOR VALVES

GRAPHIC SYMBOL	IDENT'N SYMBOL	DESCRIPTION
	IV	ISOLATING VALVE
	NV	FINE REGULATING OR NEEDLE VALVE
	NRV	NONRETURN OR CHECK VALVE
	PV	PRESSURE REDUCING VALVE
	PrV	PRESSURE RELIEF OR SAFETY VALVE
LV	LV	LEVEL CONTROL OR FLOAT OPERATED VALVE
SdV	SdV	SOLENOID VALVE TO CLOSE ON ELECTRIC SUPPLY FAILURE
SdV	SdV	SOLENOID VALVE TO OPEN ON ELECTRIC SUPPLY FAILURE
ON SdV	SdV	THREE WAY SOLENOID VALVE
	DmV	DIAPHRAGM VALVE TO CLOSE ON AIR FAILURE (ARROWS USED AS FOR SOLENOID VALVES)
	DmV	DIAPHRAGM CONTROL VALVE WITH POSITIONER
SYMBOLS FOR ELECTRICAL & PNEUMATIC SIGNALS		
▶		20 PSI INSTRUMENT AIR SUPPLY — FILTERED AND REGULATED (CAI)
▷		100 PSI AIR SUPPLY (CAS)
		PROCESS FLOW LINE
		TRANSMITTED PNEUMATIC SIGNAL (3-15 PSIG)
- - - -		TRANSMITTED DIRECT CURRENT SIGNAL (4-20 mA)
- - mV - -		TRANSMITTED ELECTRICAL SIGNAL OTHER THAN 4-20mA eg D - DIGITAL, DP - DIGITAL PULSE, mV - MILLIVOLT, R - RESISTANCE TEMP DEVICE EXTENSION WIRE, V - VOLT
◇		240V AC SUPPLY
◆		

THIS DRAWING REDUCED TO HALF SIZE

ABBREVIATIONS

AIR CIRCUIT BREAKER	ACB
ALARM	ALM
ALTERNATE	ALT
ALTERNATING CURRENT	AC
ALTERNATOR	ALT
AMPERE	A, AMP
AMPERE HOUR	AH
AUTOMATIC	AUTO
AUXILIARY	AUX
BATTERY	BAT
CAPACITY	CAP
CEILING	CLG
CENTRE	CTR
CIRCUIT	CCT
COMPRESSED AIR INSTRUMENT	CAI
COMPRESSED AIR SERVICE	CAS
CONDUCTOR	COND
CONTROL	CONT
CONTROL BOARD	CB
CONTROL DESK	CD
CONTROL STATION	CS
CONDUIT	CND
CONTINUED	CONT'D
CURRENT TRANSFORMER	CT
CYCLES PER SECOND (HERTZ)	HZ
DIAGRAM	DIAG
DIGITAL	D
DIFFERENTIAL	DIFF
DIRECT CURRENT	DC
DISCONNECT	DISC
DRAWING	DWG
ENGINE	ENG
FEET	FT
FLAME PROOF	FP
FLOAT SWITCH	FS
FORWARD	FWD
FUTURE	FUT
HEATER	HTR
HORIZONTAL	HORIZ
INTERLOCK	INTLK
INSTRUMENT AIR	IA
INSTRUMENT CUBICLE	IC
JUNCTION BOX	JB
KILOVOLT	KV
KILOVOLT - AMPERE	KVA
KILOWATT HOUR	KWH
LIGHTING	LTG
LIMIT SWITCH	LS
LINK	LK
MANUAL	MAN
MAXIMUM	MAX
MECHANICAL	MECH
MEDIUM	MED
MEDIUM PRESSURE, SLUDGE GAS	MSG
METER	M
MILLIAMPERE	mA
MILLIGRAMS PER LITER	mGA
MILLION GALLONS PER DAY	mG/D
MILLIVOLT	mV
MINIMUM	MIN
MOTOR	M
MOTOR LOAD CENTRE	MLC
MOUNTED	MTD
NEGATIVE	NEG
NEUTRAL	N
NORMALLY CLOSED	NC
NORMALLY OPEN	NO
NORTH	N
NUMBER	NO
OPEN	OP
PARTS PER MILLION	PPM
PNEUMATIC	PNEU
POLYVINYL CHLORIDE	PVC
POSITIVE	POS
POWER	PWR
POWER CENTRE	PC
POWER CONTROL CENTRE	PCC
POWER FACTOR	PF
PROTECTION	PROT
RADIUS	R
REQUIRED	REQD
RESISTOR	RES
REVERSE	REV
REVOLUTIONS PER MINUTE	RPM
SQUIRREL CAGE	SC
SUPERVISORY CONTROL CENTRE	SCC
SWITCHBOARD	SWBD
SWITCHGEAR	SWGR
SYNCHRONOUS	SYN
TELEPHONE	TEL
TEMPERATURE	TEMP
TERMINAL	TERM
THAT IS	IE
TRANSFORMER	TRANS
TYPICAL	TYP
UNDERGROUND	UG
UTILITY STATION	US
VERTICAL	VERT
VOLT	V
VOLTAGE TRANSFORMER	VT
VOLTS ALTERNATING CURRENT	VAC
VOLTS DIRECT CURRENT	VDC
VOLTAMPERE	VA
VOLT AMPERES REACTIVE	VAR
VOLUME	VOL
WATT	W
WATTHOUR	WH
WITH	W/
WITHOUT	W/O
INTERLOCK	INTLK
OPEN	OP
WEATHER PROOF	WP
EXTRA HIGH VOLTAGE	EHV
HIGH VOLTAGE	HV
MEDIUM VOLTAGE	MV
LOW VOLTAGE	LV

SCC/PCC/PC NUMERICAL PREFIXES

SUPERVISORY CONTROL CENTRE	SCC	60
ADMINISTRATION	PC	61
OUTFALL PUMPING STATION	PCC	72
HV SWITCHING AND METERING STRUCTURE	PC	[illegible]
INFLUENT PUMPING	PCC	17
PRIMARY TREATMENT	PCC	26
SECONDARY TREATMENT	PCC	32
SLUDGE DIGESTION	PCC	52
POWER GENERATION	PCC	62
MAINTENANCE	PC	63
CHLORINATION - INCINERATION	PCC	71

ELECTRICAL PLANT IDENTIFICATION

THE FOLLOWING SUFFIXES ARE USED:

TERMINATION PANEL	TP
BATTERY	B
BATTERY CHARGER	BC
CONTROL BOARD	CB
CONTROL DESK	CD
DC DISTRIBUTION BOARD	DC
HIGH VOLTAGE SWITCHGEAR	H
INSTRUMENT CUBICLE	IC
LOW VOLTAGE SWITCHBOARD, PANELBOARD	L
MEDIUM VOLTAGE SWITCHGEAR	M
CABLE TRAY	T
RELAY BOARD OR RACK	R

EXAMPLE : 17MA22

PCC PREFIX — MV SWITCHBOARD — ELEC COMPONENT PREFIX — A, B, C AS REQD

INSTRUMENTATION LOOP IDENTIFICATION

EXAMPLE : 1701LAI

PCC PREFIX — LOOP SUFFIX 01 - 99 — INSTRUMENT SYMBOL

THIS DRAWING REDUCED TO HALF SIZE

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

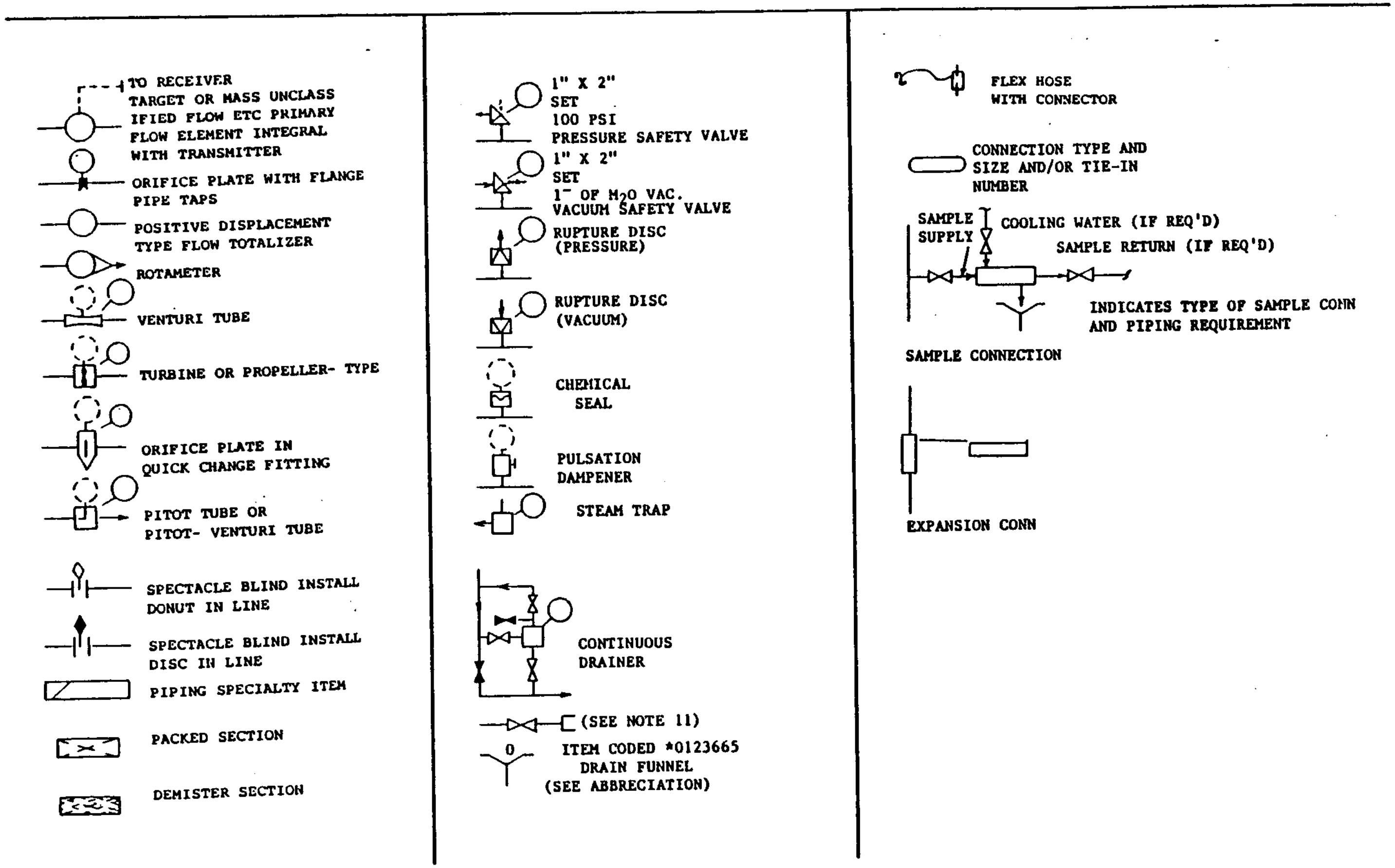
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

MISCELLANEOUS



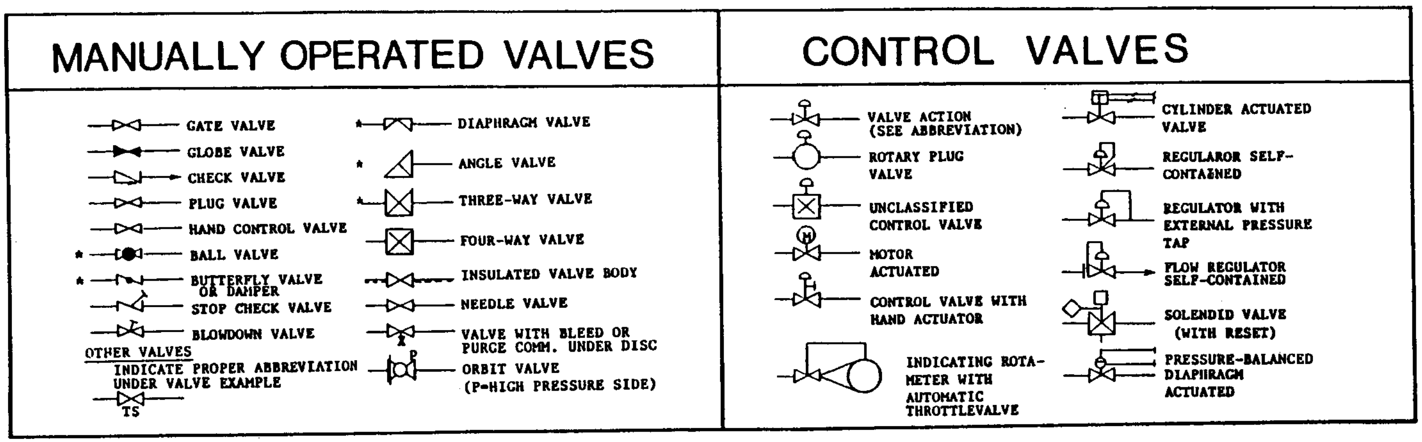
NASA/USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT



ABBREVIATIONS

BD - BLOWDOWN
CSC - CAR SEAL CLOSE
CSO - CAR SEAL OPEN
CW - COOLING WATER
(F) - FURNISHED
(F&P) - FURNISHED AND PIPED
FC - FAIL CLOSE
FI - FAIL INDETERMINATE
FL - FAIL LOCKED
FO - FAIL OPEN
HP - HORSE POWER _ - HIGH PRESS.
H.PT - HIGH POINT
IAS - INSTRUMENT AIR SUPPLY
LC - LOCK CLOSE
LO - LOCK OPEN
LP - LOW PRESSURE
L.PT - LOW POINT
ORB - ORBIT VALVE
T/T - TANGENT TO TANGENT
FP - FULL POINT
PO - PUMP OUT
SC - SAMPLE CONNECTION
SO - STEAM OUT
SP - SET POINT
SP. GR. - SPECIFIC GRAVITY
C - CHEMICAL DRAIN
O - OILY WATER DRAIN
S - STORM WATER DRAIN
CO - CHAIN OPERATED
GO - GEAR OPERATED
OV - OPERATING VALVE
TSO - TIGHT SHUT OFF
FD - FLEX-DISC VALVE
SS - SOFT SEAT VALVE
TS - GENERAL TWIN-SEAL
Ic - INSULATION COLD
Ih - INSULATION HOT
Is - INSULATION SAFETY

NASA/USRA

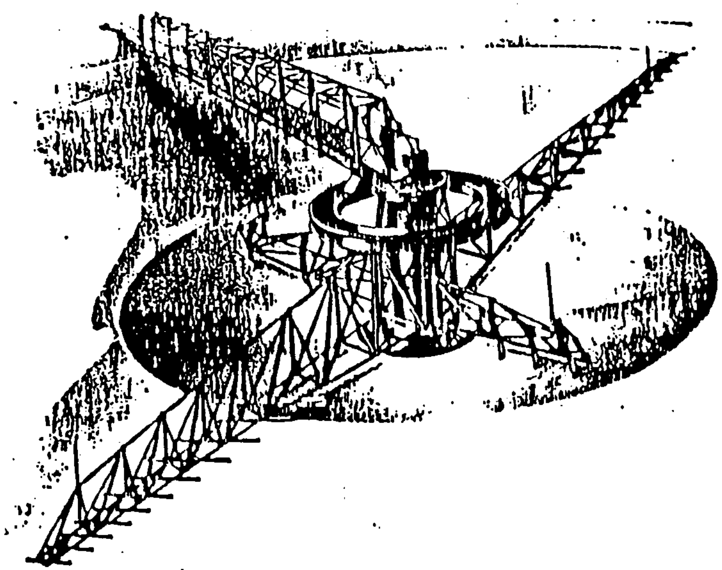
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

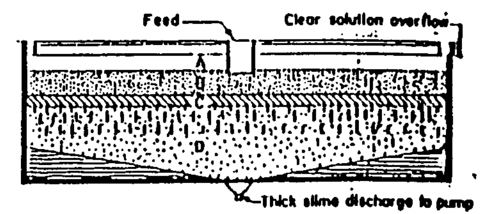
DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

ORIGINAL PAGE IS OF POOR QUALITY





Section through a continuous thickener illustrating position of four zones of settling pulp

Zone A: Clear water or solution

Zone B: Pulp of feed consistency

Zone C: Pulp in transition from B to D consistency

Zone D: Pulp in compression

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

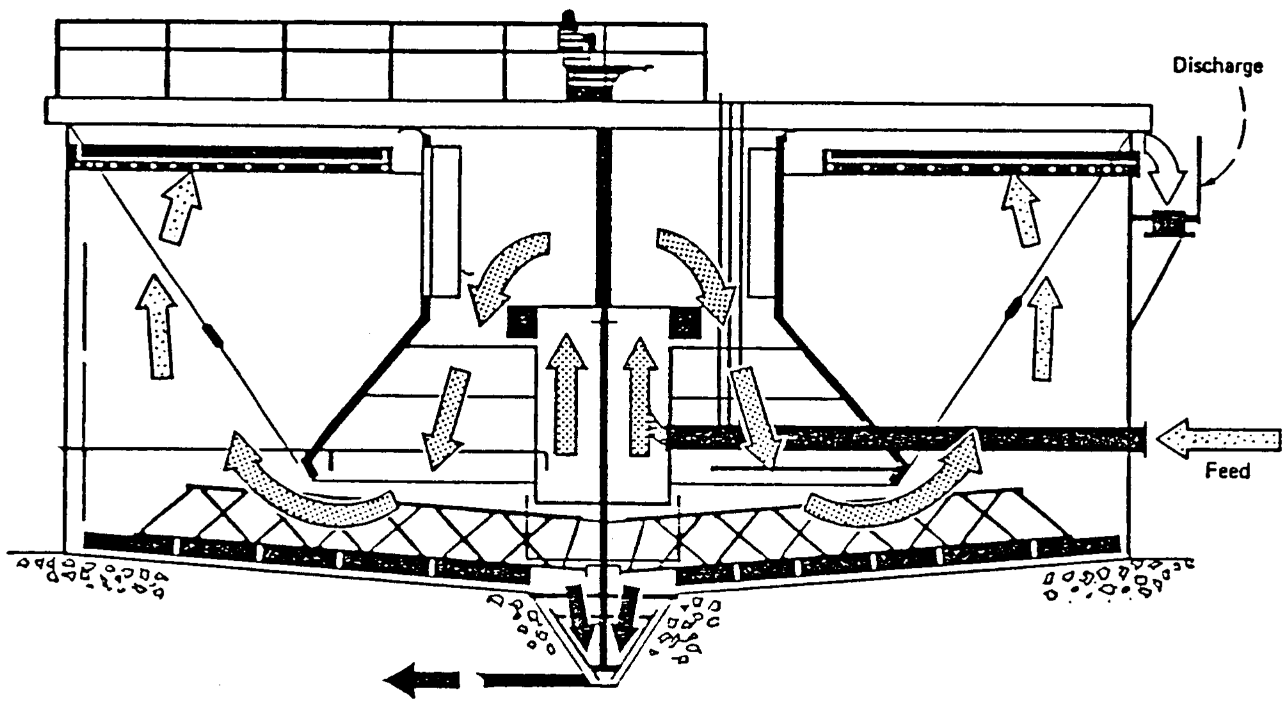
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

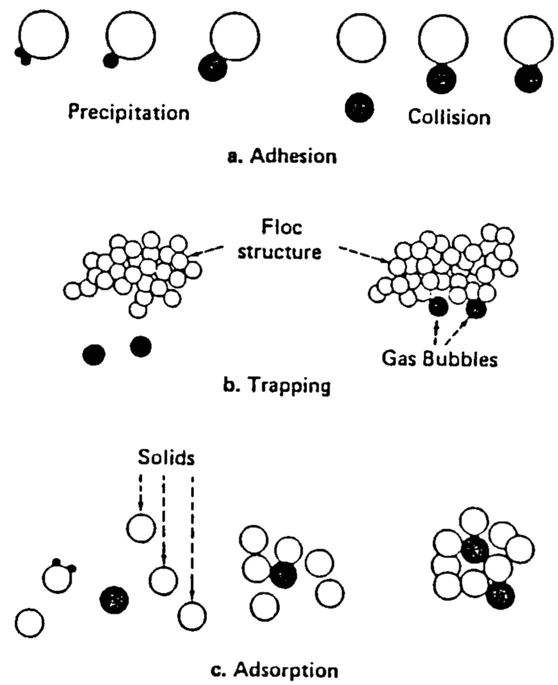
PAGE:

ORIGINAL PAGE IS OF POOR QUALITY



Solids-contact unit combines in a single basin mixing, coagulation and flocculation, liquid-solids separation and sludge removal

	NASA / USRA	DEPARTMENT OF CHEMICAL ENGINEERING
	INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	ADVANCED DESIGN PROJECT
		APPROVED BY: K. FOTOUH
		PAGE:



Mechanisms for attachment of gas bubbles to solids or oil

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

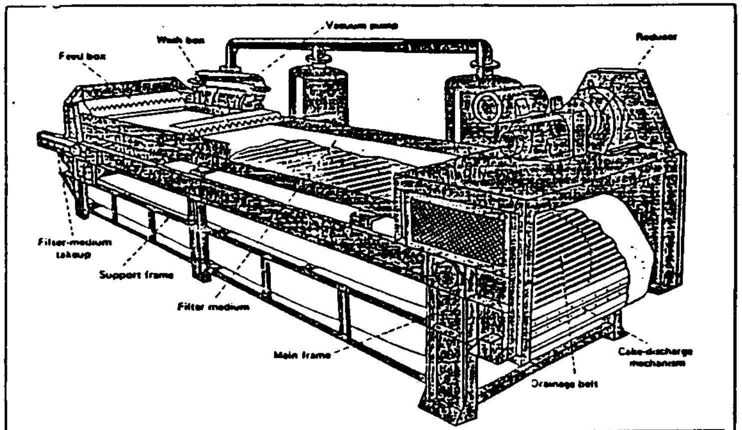
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUE

PAGE:

CONTINUOUS HORIZONTAL FILTERS



Horizontal-belt filter is best used with slurries containing granular solids

Advantages

> Provide effective filtering of heavy, dense solids

> Allow flooding of the cake with wash solvent

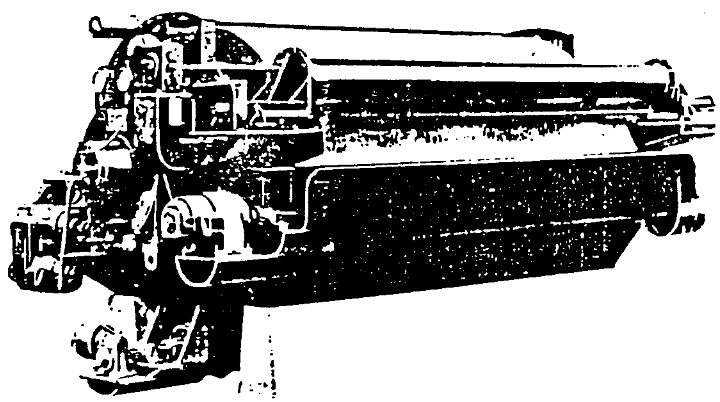
> Easily adaptable to true countercurrent leaching or washing

Disadvantages

> More expensive to build than drum filters

> Use a relatively large amount of floor space per unit of filtering area

NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:



Continuous-vacuum precoat filter, 5 ft, 3 in. diameter x 8 ft face.
(Courtesy Dorr-Oliver, Inc.)

CONTINUOUS ROTARY DRUM FILTERS

Advantages

> Usually designed as effective continuous filters

> Low labor users and efficient adjuncts to continuous processes

> Maintenance cost are usually low

Disadvantages

> System must be maintained

> Cannot be used with filtrates that are volatile

> Most systems cannot handle difficulty filterable compressible solids

Applications for granular-media gravity filters

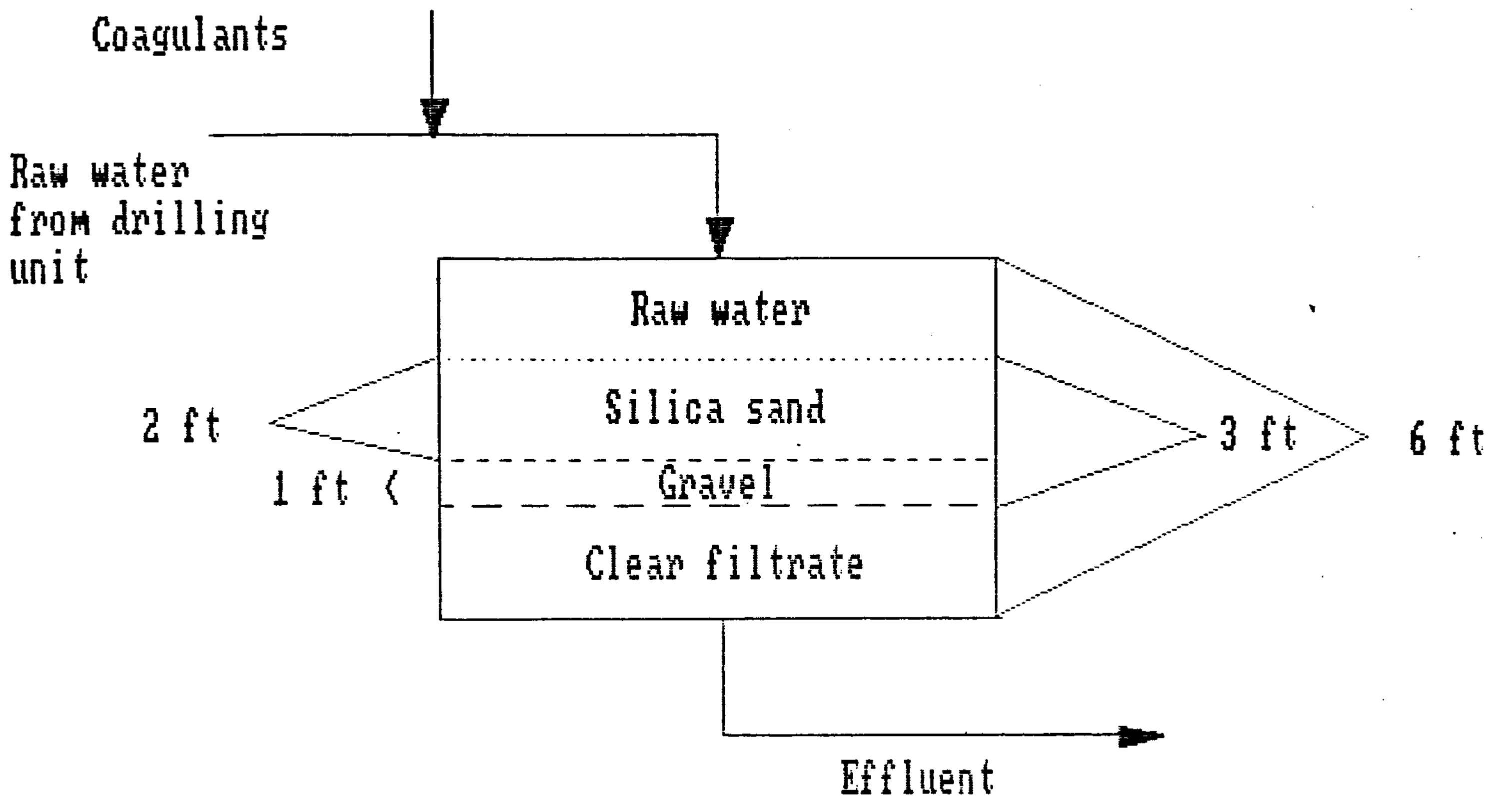
Shallow-bed filters
(single medium, or multiple media)

1. Polishing clarified water.
2. Filtering flocculated low-turbidity waters.
3. Filtering sidestream from cooling towers.
4. Filtering waste solids.
5. Filtering tertiary effluents
6. Filtering after physical/chemical treatment.
7. Clarifying chemical processing streams
8. Recovering valuable suspended-solids products.

Deep-bed coarse-media filters
(single medium, or multiple media)

1. Clarifying steel-mill wastes.
2. Filtering tertiary effluents.

SAND FILTER



NASA / USRA

INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II-TASK 1-B

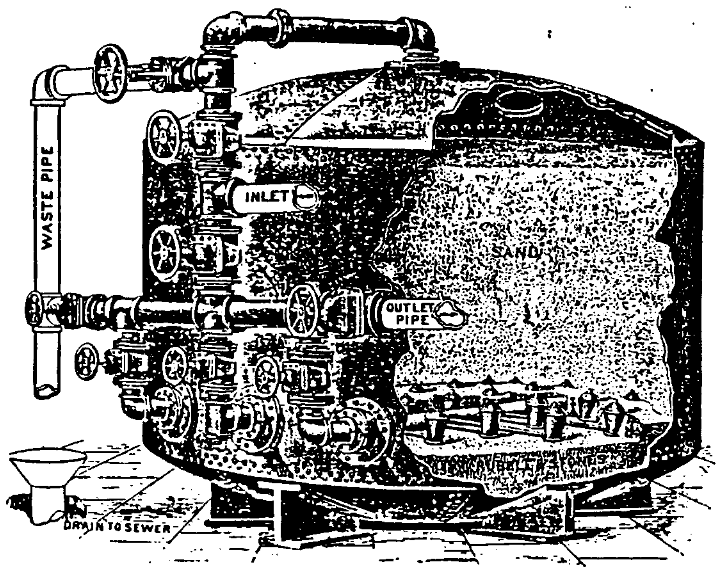
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

SAND FILTERS



THE JEWELL PRESSURE FILTER.

Advantages

> Very suitable for granular, or sandy crystalline solids

> Low capital costs

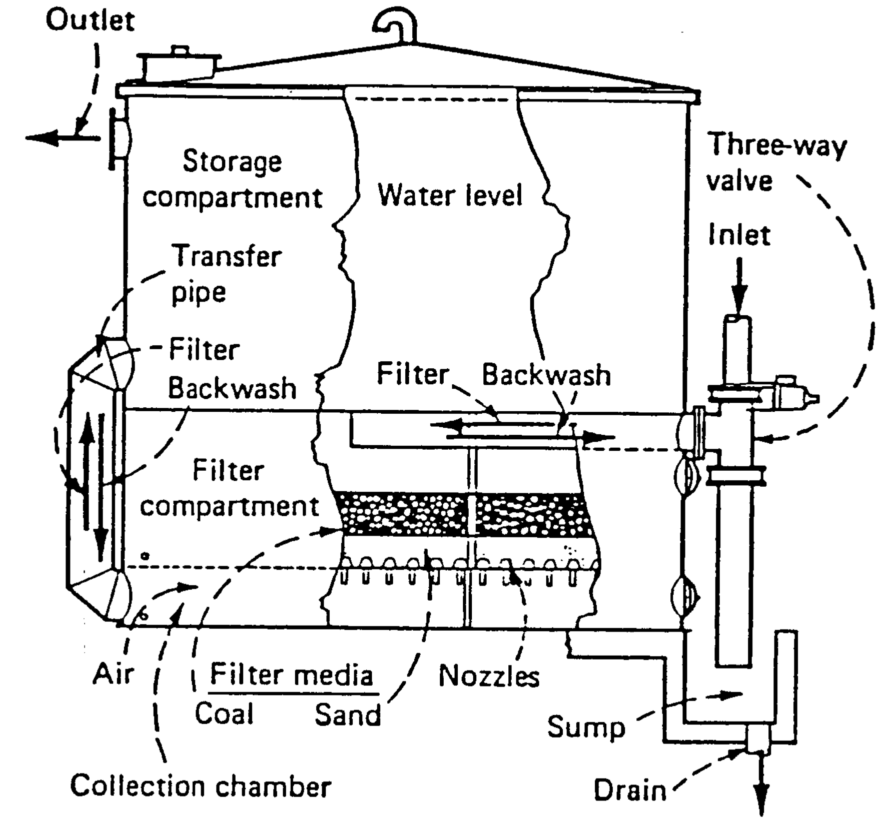
> Excellent equipment size range

Disadvantages

> Severely limited when handling ease of cake discharge

> Unacceptable for multiple-particle-size

	NASA / USRA **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:



Granular-media filter operates on a controlled cycle

	NASA / USRA	DEPARTMENT OF CHEMICAL ENGINEERING
	INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	ADVANCED DESIGN PROJECT
		APPROVED BY: K. FOTOUH
		PAGE:

DECISION CHART

EQPT	CONTINUOUS OPERATION	EQUIPMENT SIZE	OPTIMUM PARTICLE SIZE	POWER CONSUMPTION	MAINTENANCE	OPTIMUM CONCENTRATION	TOTAL
HORZONTAL FILTERS	8	5	7	6	8	8	'730
ROTARY DRUM FILTERS	8	7	8	5	6	9	740
SAND FILTERS	6	7	8	8	9	8	770
SCREENS	7	9	9	7	7	7	760
	(20)	(10)	(20)	(10)	(20)	(20)	

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

DESIGN ASSUMPTIONS

Flowrate 10,000 gallons/day

Gravity = 3/8 earths gravity

Stokes law applies to settling

Return sludge concentration is 7000 mg/L

Temperature 20° C

DESIGN RECCOMMENDATIONS

Primary Clarifier

SETTLING VELOCITIES	12 - 18 m^3/m^2day
SURFACE AREA	2.7 m^2
DEPTH OF TANK	1.0 m
TOTAL VOLUME	2.7 m^3
DETENTION TIME	2 hours

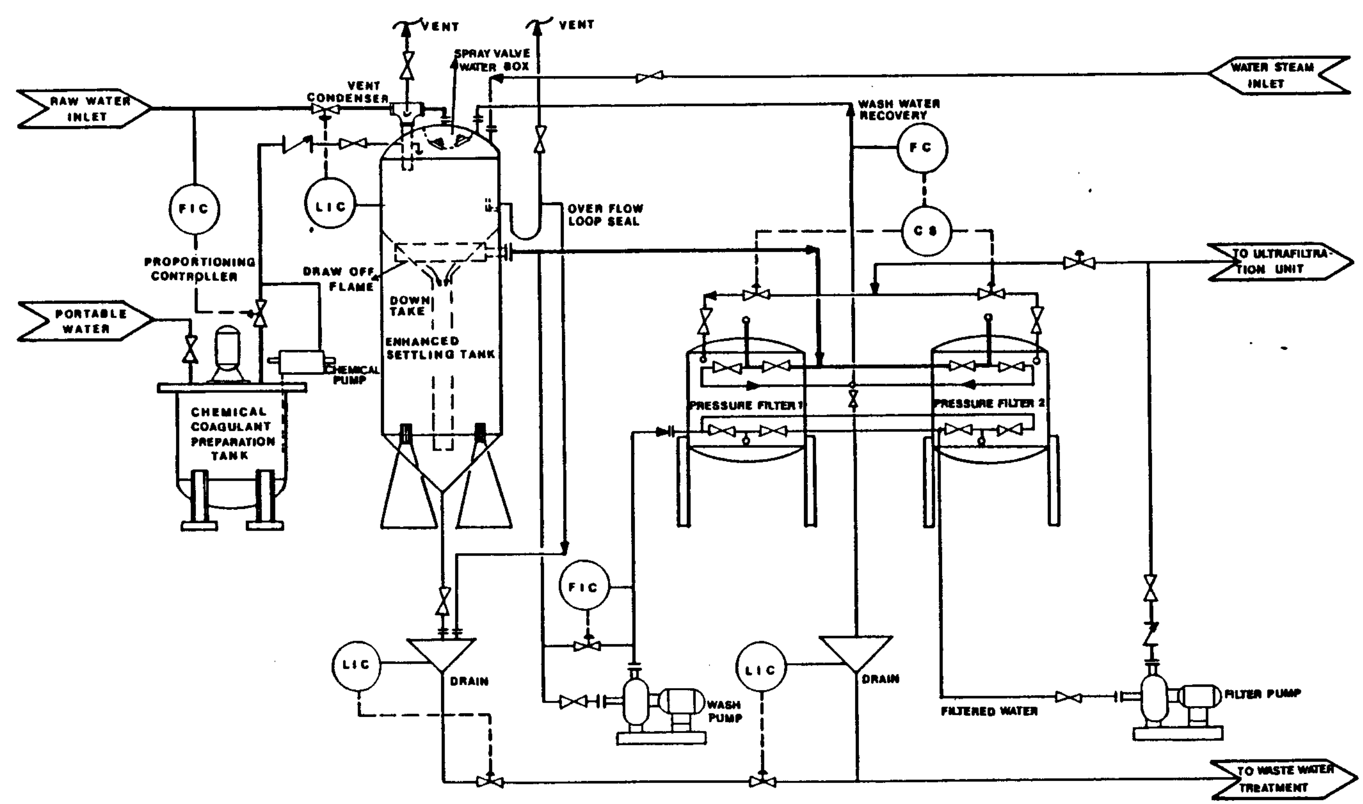
Biological Reactor

REACTOR VOLUME	1.5 m^3
AERATION TIME	60 min (approx.)
OXYGEN REQUIREMENT	7.0 kg/day
TREATMENT EFFICIENCY	97%

Secondary Clarifier

SURFACE AREA	4.7 m^2
DEPTH OF TANK	1.5 m
TOTAL VOLUME	7.1 m^3

2 SUSPENDED SOLIDS REMOVAL UNIT



NASA/USRA

INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL
ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

ORIGINAL PAGE IS
OF POOR QUALITY

Technique	Applications	Limitations	Relative costs: Capital	Relative costs: Operating	Comments
Vapor-compression evaporation	Concentration of wastewater or cooling-tower blowdown Concurrent production of high-purity water	Not for organics that form azeotropes or steam-distill Fouling must be controllable	High	High	Rapid growth High-quality distillate Handles broad range of contaminants in water
Waste heat evaporation	Concentration of wastewater Condensate recovery	Not for organics that form azeotropes or steam-distill	Medium	Medium	Not widely used now Future potential good
Reverse osmosis, ultrafiltration	Removal of ionized salts, plus many organics Recovery of heavy metals, colloidal material Production of ultrapure water	Fouling-sensitive Stream must not degrade membranes Reject stream may be high-volume	Medium	Medium	Future potential strong Intense application development underway
Electrodialysis	Potable water from saline or brackish source	Limited to ionizable salts	Medium-high	Medium	Modest future potential
Steam stripping	Recovery of process condensates and other contaminated waters Removal of H_2S, NH_3, plus some light organics	Stripped condensates may need further processing	Medium	Medium-high	Well-established as part of some processes
Combination wet/dry cooling towers	Puts part of tower load on air fins Can cut fogging	Costly compared with wet cooling tower	Medium	Medium	Growth expected in arid areas
Air-fin cooling	Numerous process applications	For higher-level heat transfer Can be prone to freeze-up, waxing	Medium	Medium	Well-established Good for higher-temperature heat rejection
Sidestream softening	Reduce cooling-tower blowdown	Dissolved solids must be removable Control can be difficult	Low-medium	Low-medium	Not widely used Future potential good

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

Technique	Applications	Limitations	Relative costs: Capital	Relative costs: Operating	Comments
Vapor-compression evaporation	Concentration of wastewater or cooling-tower blowdown Concurrent production of high-purity water	Not for organics that form azeotropes or steam-distill Fouling must be controllable	High	High	Rapid growth High-quality distillate Handles broad range of contaminants in water
Waste heat evaporation	Concentration of wastewater Condensate recovery	Not for organics that form azeotropes or steam-distill	Medium	Medium	Not widely used now Future potential good
Reverse osmosis, ultrafiltration	Removal of ionized salts, plus many organics Recovery of heavy metals, colloidal material Production of ultrapure water	Fouling-sensitive Stream must not degrade membranes Reject stream may be high-volume	Medium	Medium	Future potential strong Intense application development underway
Electrodialysis	Potable water from saline or brackish source	Limited to ionizable salts	Medium-high	Medium	Modest future potential
Steam stripping	Recovery of process condensates and other contaminated waters Removal of H_2S, NH_3, plus some light organics	Stripped condensates may need further processing	Medium	Medium-high	Well-established as part of some processes
Combination wet/dry cooling towers	Puts part of tower load on air fins Can cut fogging	Costly compared with wet cooling tower	Medium	Medium	Growth expected in arid areas
Air-fin cooling	Numerous process applications	For higher-level heat transfer Can be prone to freeze-up, waxing	Medium	Medium	Well-established Good for higher-temperature heat rejection
Sidestream softening	Reduce cooling-tower blowdown	Dissolved solids must be removable Control can be difficult	Low-medium	Low-medium	Not widely used Future potential good

NASA / USRA

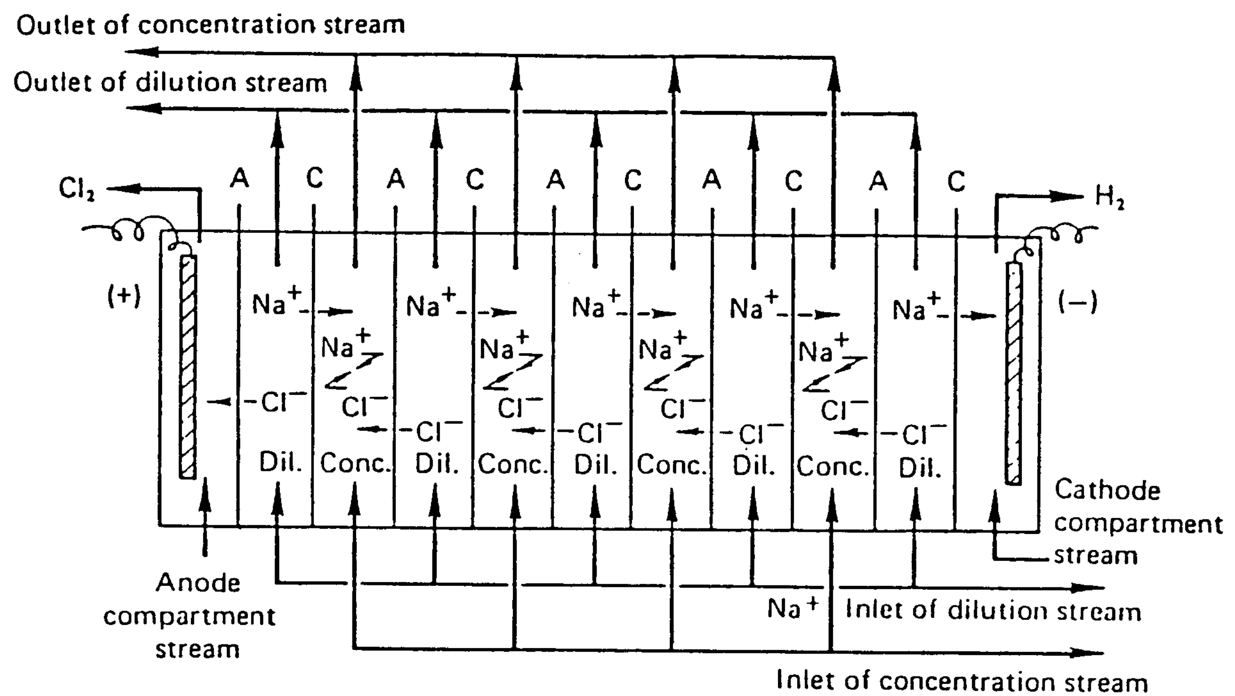
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

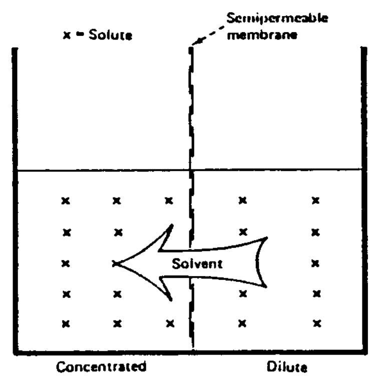
APPROVED BY: K. FOTOUH

PAGE:

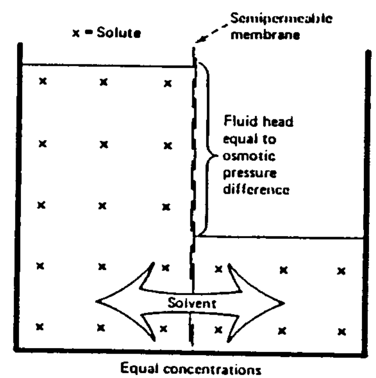


Schematic of electrodialysis apparatus

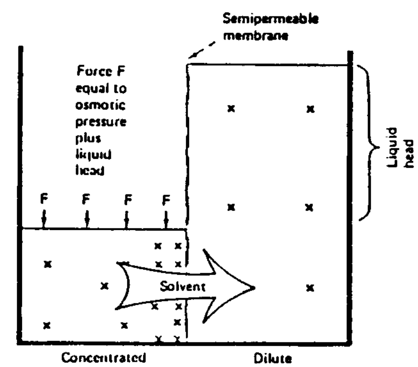
	NASA / USRA **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:



DIRECT OSMOSIS: solvent flows spontaneously through semipermeable membrane

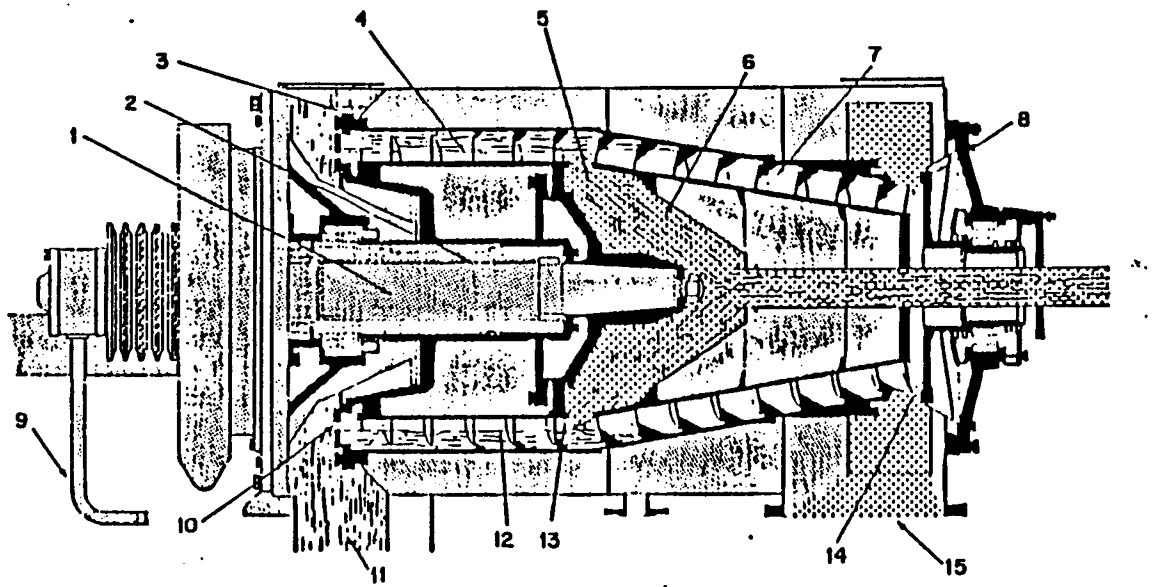


SOLVENT FLOW stops when the osmotic pressures of two solutions are equal



REVERSE OSMOSIS requires applied force equal to osmotic pressure plus liquid head

	NASA / USRA	DEPARTMENT OF CHEMICAL ENGINEERING
	INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	ADVANCED DESIGN PROJECT
		APPROVED BY: K. FOTOUH
		PAGE:



Continuous horizontal or vertical vibratory centrifuge. (1) Conveyor output eccentric shaft, (2) bowl output shaft, (3) effluent bowl head, (4) conveyor, (5) bowl, (6) feed compartment, (7) beach, (8) cake pump, (9) torque arm, (10) pool settling, (11) effluent, (12) pool volume, (13) feed ports, (14) cake ports, (15) cake solids. (*Envirotech Corp.*)

PVAM

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

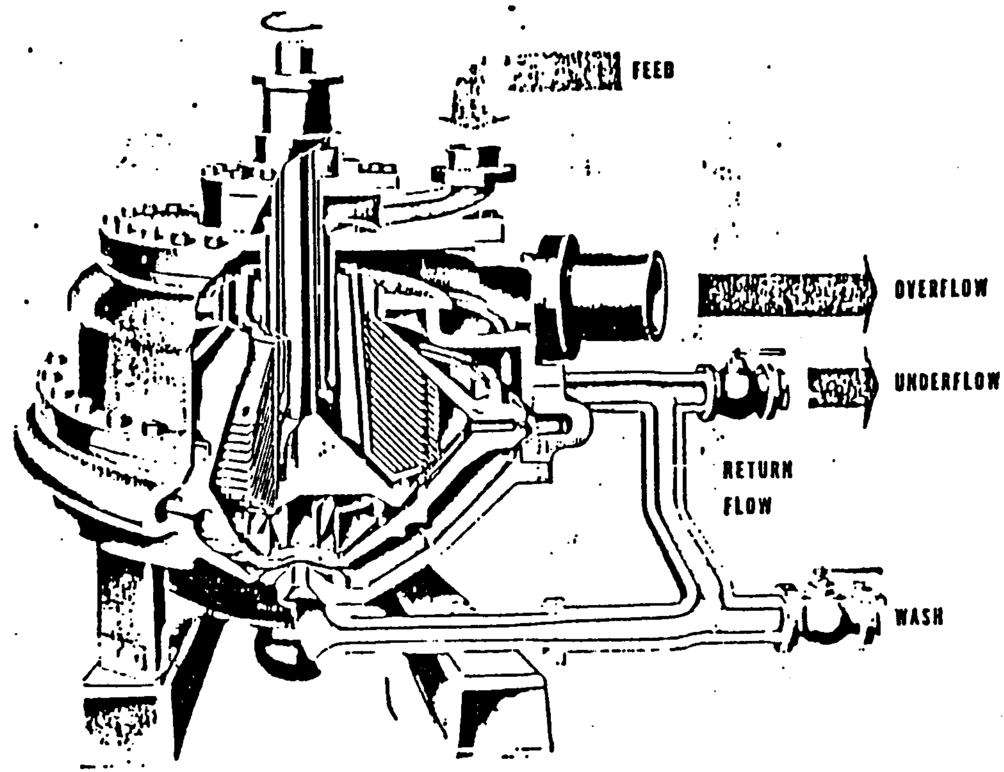
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY



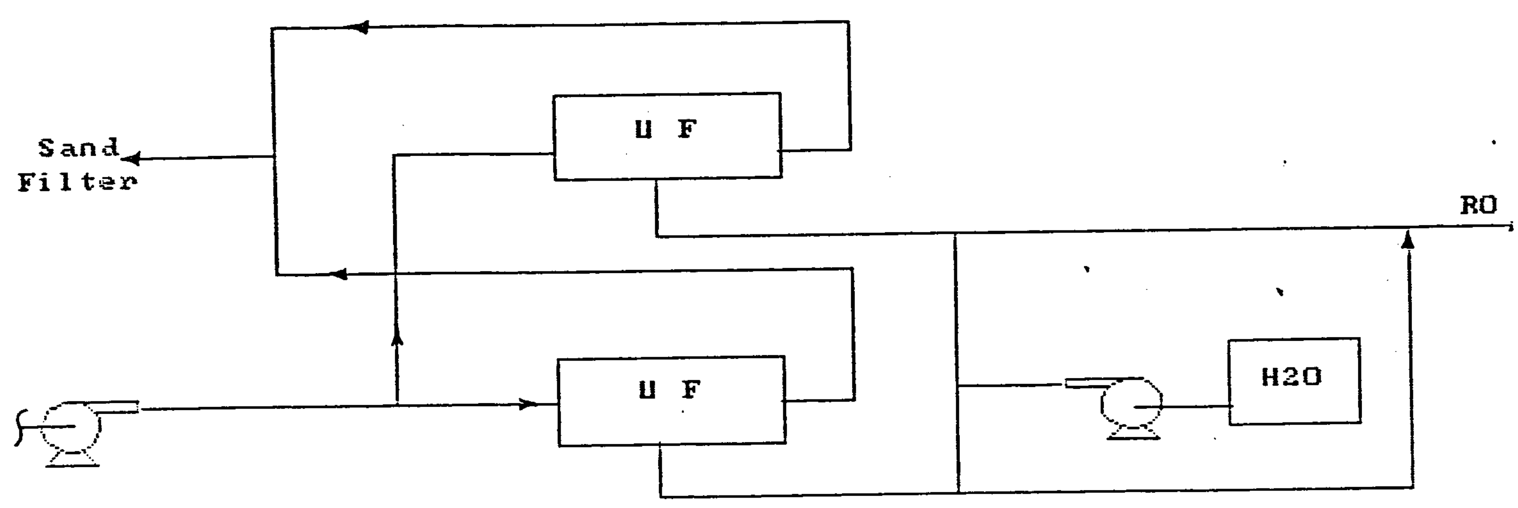
Peripheral-discharge-disk centrifuge. (*Dorr-Oliver Incorporated.*)

PVAMU	**NASA / USRA** **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

TECHNOLOGY RATINGS
Table-II

Type	Operating Temp	Particle Size Retention Range	Contin-uous Opera-tion	Relative Equipment Weight	Main-tain-ability	Total
*1	10	6	5	3	5	29
2	10	5	5	3	5	28
3	10	10	8	5	2	35
4	10	7	7	8	7	39
5	10	10	9	8	8	45

1:Continuous horizontal, conveyer type solid bowl centrifuge.
2:Peripheral-discharge-disk centrifuge.
3:Chemical coagulation & clarifiers.
4:Microfiltation.
5:Ultrafiltration.

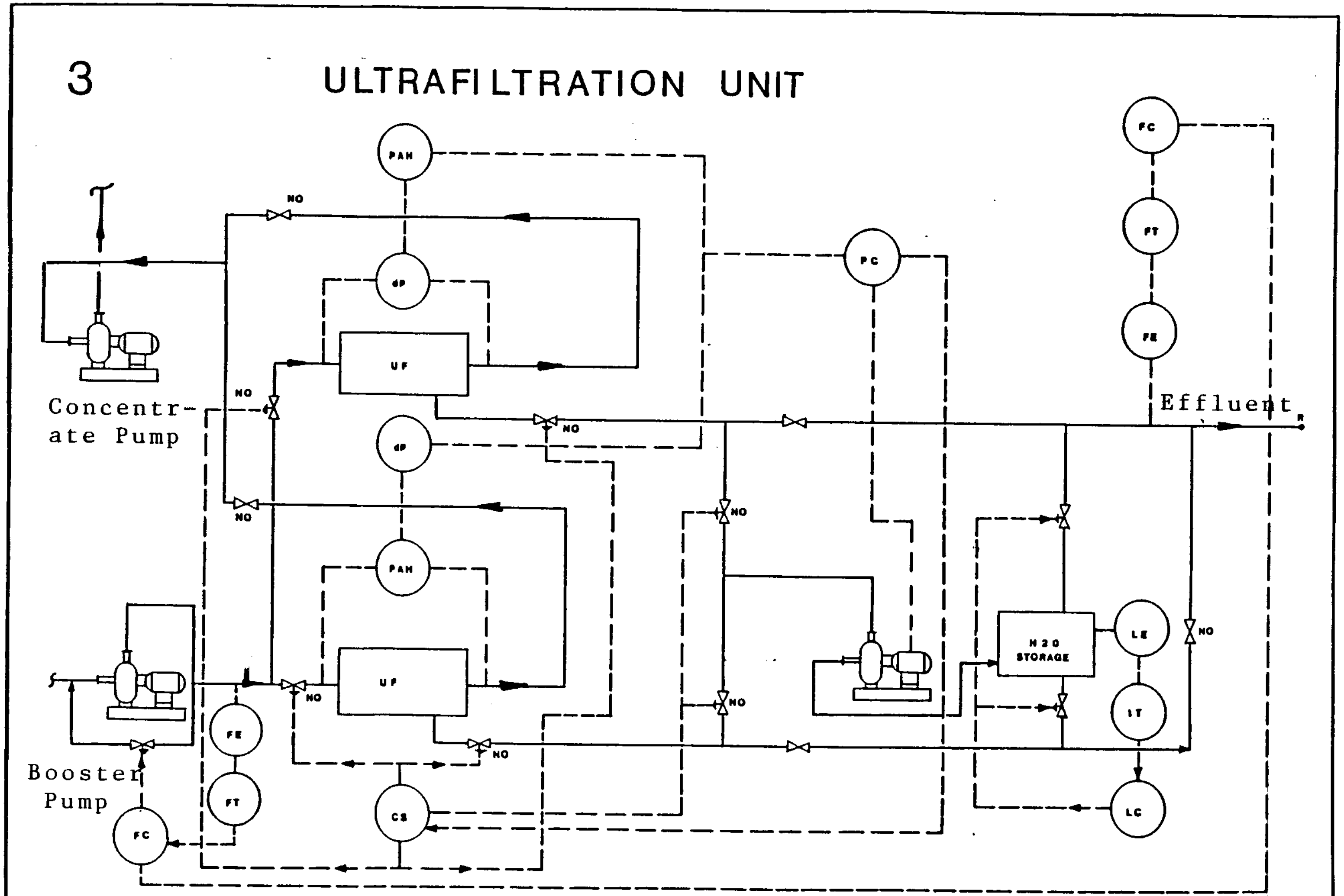


General configuration

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING	
ADVANCED DESIGN PROJECT	
APPROVED BY: K. FOTOUH	
PAGE:	



NASA/USRA
INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
K. FOTOUH
ADVANCED DESIGN PROJECT

Membrane Cleaning Techniques for Hyperfiltration

Technique	Method	Description
Physical	Mechanical	Foam ball swabbing
	Hydrodynamical	Tangential velocity variation Turbulence promoters
	Backwashing	Depressure and forced or osmotic reverse flow of *product*
	Air–Water flushing	Daily 15 min depressurized flush
	Sonication	Regular ultrasonic cleaning with wetting agent
Chemical	Reverse flow	Reverse flow direction of feed
	Additives to feed	pH control to reduce hydrolysis and scale deposit 5 ml/gal of 5% sodium hyperchlorite at pH 5 Friction reducing additives (polyethyleneglycol) soil dispersants (sodium silicate)
	Flushing with additives at low pressure	Complexing agents (EDTA, Sodium hexametaphosphate) Oxidizing agents (citric acid) Detergents (1% BIZ)
Other	Membrane replacement	High concentration of NaCl (18%)
	Inorganic membranes	*in situ* membrane replacement
	Active insoluble enzymes attached to membrane	Encourage biogrowth to consume fouling film Degradation of fouling film
	Polyelectrolyte membranes	Composite membranes or dynamic layer technique
	Precoat protection	Precoat (diatomaceous earth, activated carbon, and surface-active agent) Deposit a porous diatomaceous earth coating

Membrane Number	Salt Rejection (%)*	Flux $m^3/m^2/d$ (gfd)**	Test Conditions
NTR-1597	97	0.7(17)	0.5% NaCl solution 42 Kg/cm² (600 psig) 25°C (77°F)
NTR-1595	95	0.8(20)	
NTR-1590	90	1.2(30)	
NTR-1570	70	0.8(20)	0.5% NaCl solution 20 Kg/cm² (285 psig) 25°C (77°F)
NTR-1550	50	1.3(32)	
NTR-1530	30	1.5(37)	
NTR-1510	10	2.5(62)	

* nominal
** gallons per square foot per day

Typical rejection of organics by NTR-1597 membrane

Species	Rej. (%)
Sucrose	100
Lactose	100
Glucose	99.9
Protein	100
Water-soluble starch	100
Dyes	100
Bacteria and Virus	100
Nonionic surfactant	95~99
Anionic surfactant	90~95
Phenol	negative*
Acetic acid	**
Lactic acid	**
Alcohol	0~80***
BOD	85~99
COD	85~99

*Permeate is actually enriched due to preferential passage through the membrane.
**Dependent on pH
***Dependent on the form of alcohol

Typical rejections of inorganic ions by NTR-1597 membrane

IONS	Rej.(%)
Na^+	95 ~ 97
K^+	94 ~ 97
Ca^{2+}	96 ~ 99
Mg^{2+}	96 ~ 99
Cu^{2+}	96 ~ 99
Ni^{2+}	97 ~ 99
Sn^{2+}	98 ~ 99
Cd^{2+}	98 ~ 99
Al^{3+}	99
Fe^{3+}	99
Cl^-	95 ~ 97
F^-	95 ~ 97
NO_3^-	93 ~ 96
CN^-	90 ~ 95
SO_4^{2-}	99
PO_4^{3-}	99

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. POTOUH
PAGE:

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

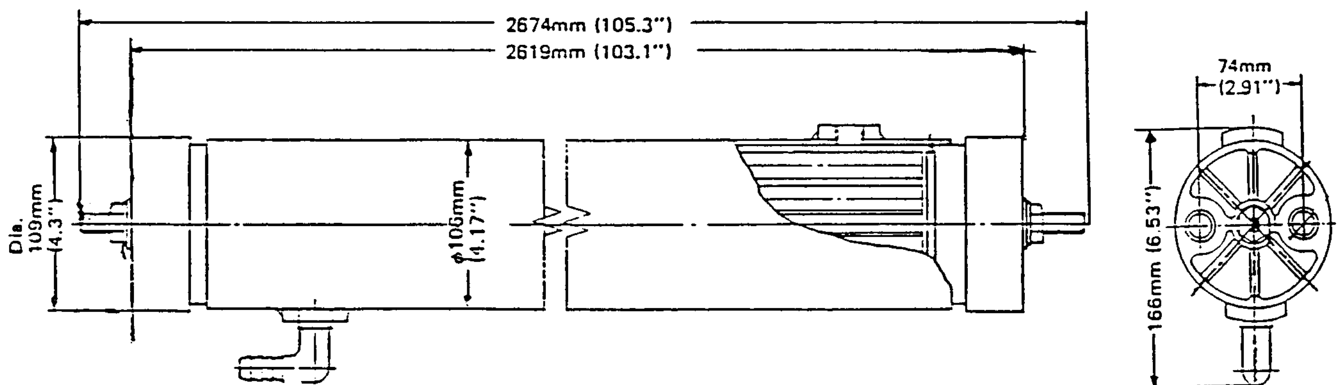
Module Specifications

Number of Tubes	18
Membrane Area	1.62m^2 (17.4 sq. ft.)
Diameter	109mm (4.3")
Length	2619mm (103")

NTR-1597 SERIES P18-A TUBULAR MODULE

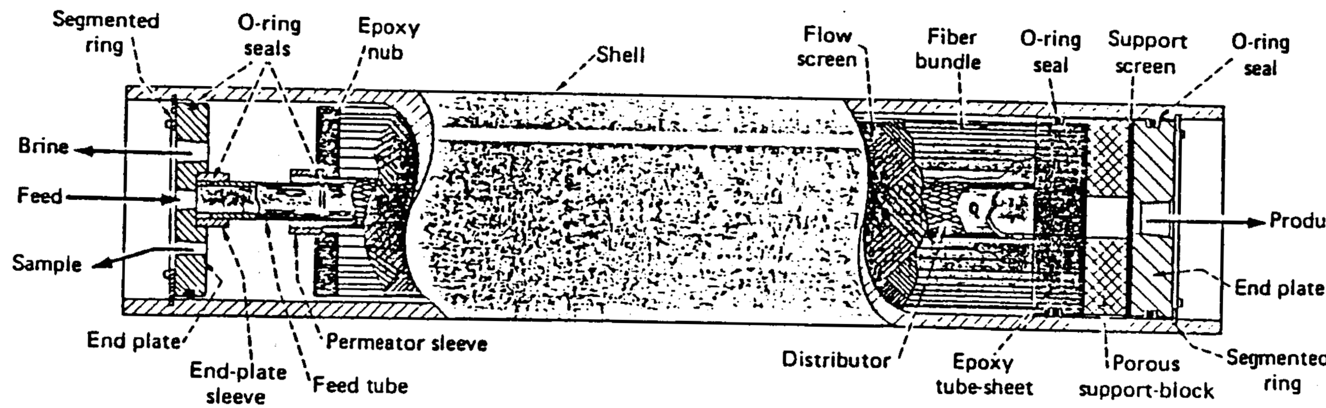
NITTO DENKO AMERICA, INC.

1. Feed Concentrate Header
2. Air Vent
3. FPR Tube (18)
4. Return Header
5. Permeate Nozzle



Construction and Dimension of P18A Modules

PVAM	NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:



NASA / USRA

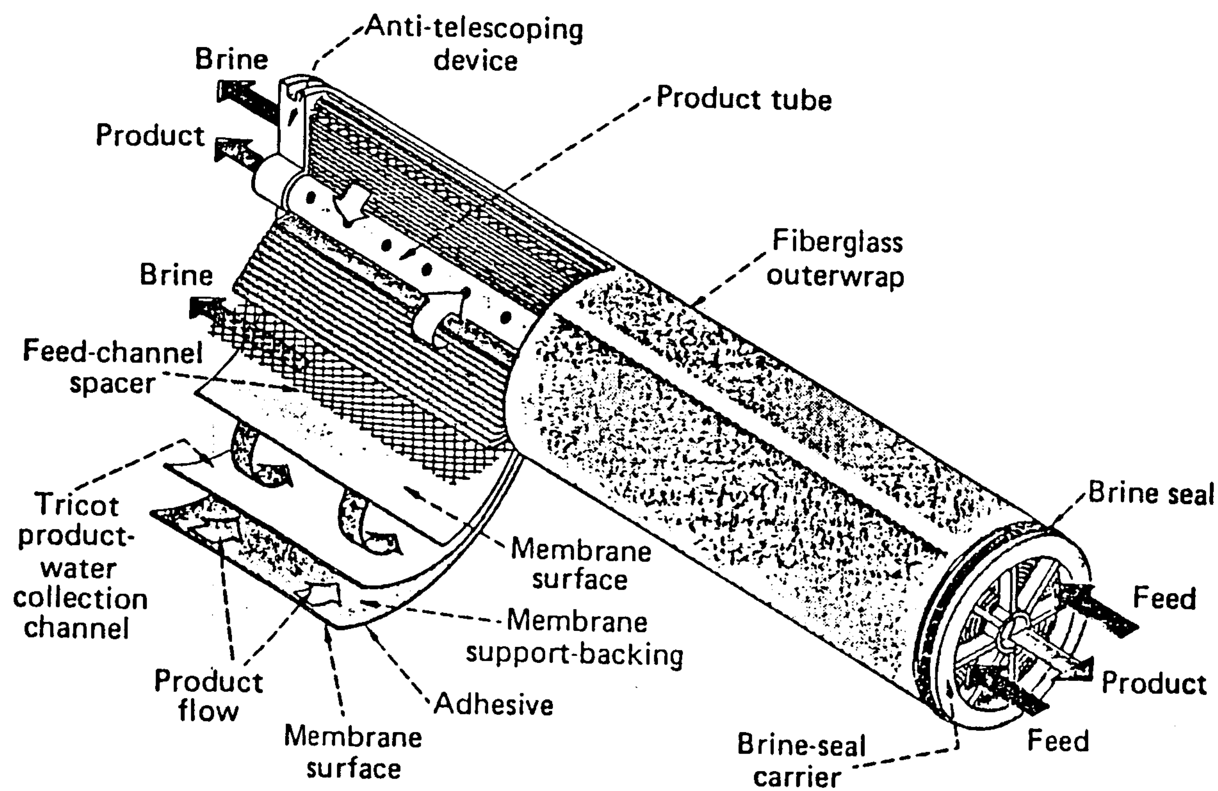
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

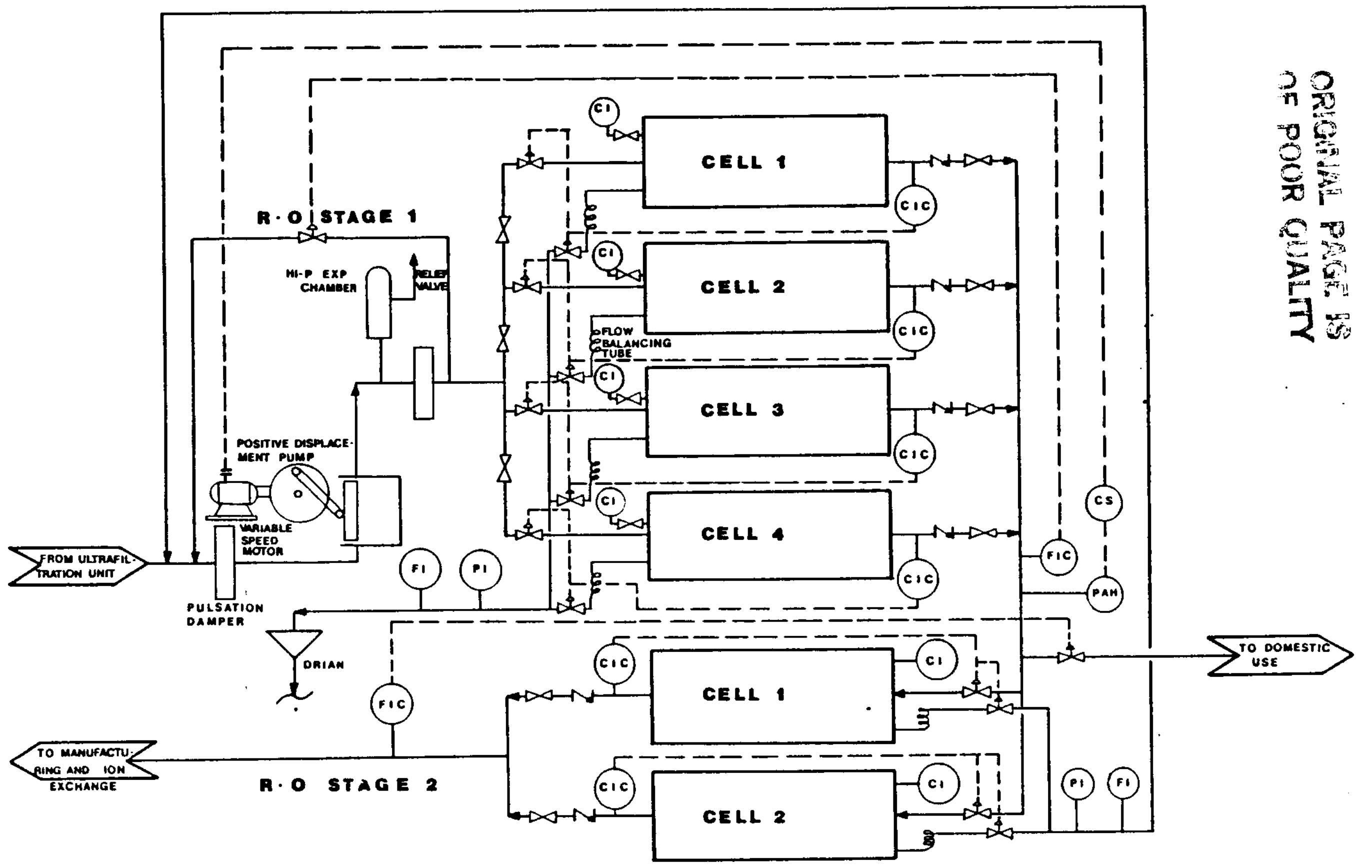
ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

4

REVERSE OSMOSIS UNITS 1 & 2



NASA/USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TAS K 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

DISINFECTANTS

TECHNOLOGY REVIEW

CHLORINE

FLOURINE

OZONE

ULTRAVIOLET LIGHT

CHLORINE DIOXIDE

SODIUM HYPOCHLORITE

CHLORINE - effective at low concentrations, forms a residual, and can be manufactured from available brine.

DEPARTMENT OF CHEMICAL ENGINEERING

SELECTION OF DISINFECTANTS

(1) Ultraviolet light for immediate use of drinking water and for ion free industrial water.

(2) Chlorine for all treated water that will be stored, and pre- and post- chlorinatation of wastewater.

OBJECTIVE: MANUFACTURE OF CHLORINE FOR THE PURIFICATION OF WATER.

METHOD: ELECTROLYSIS OF BRINE IN A DIAPHRAGM CELL.

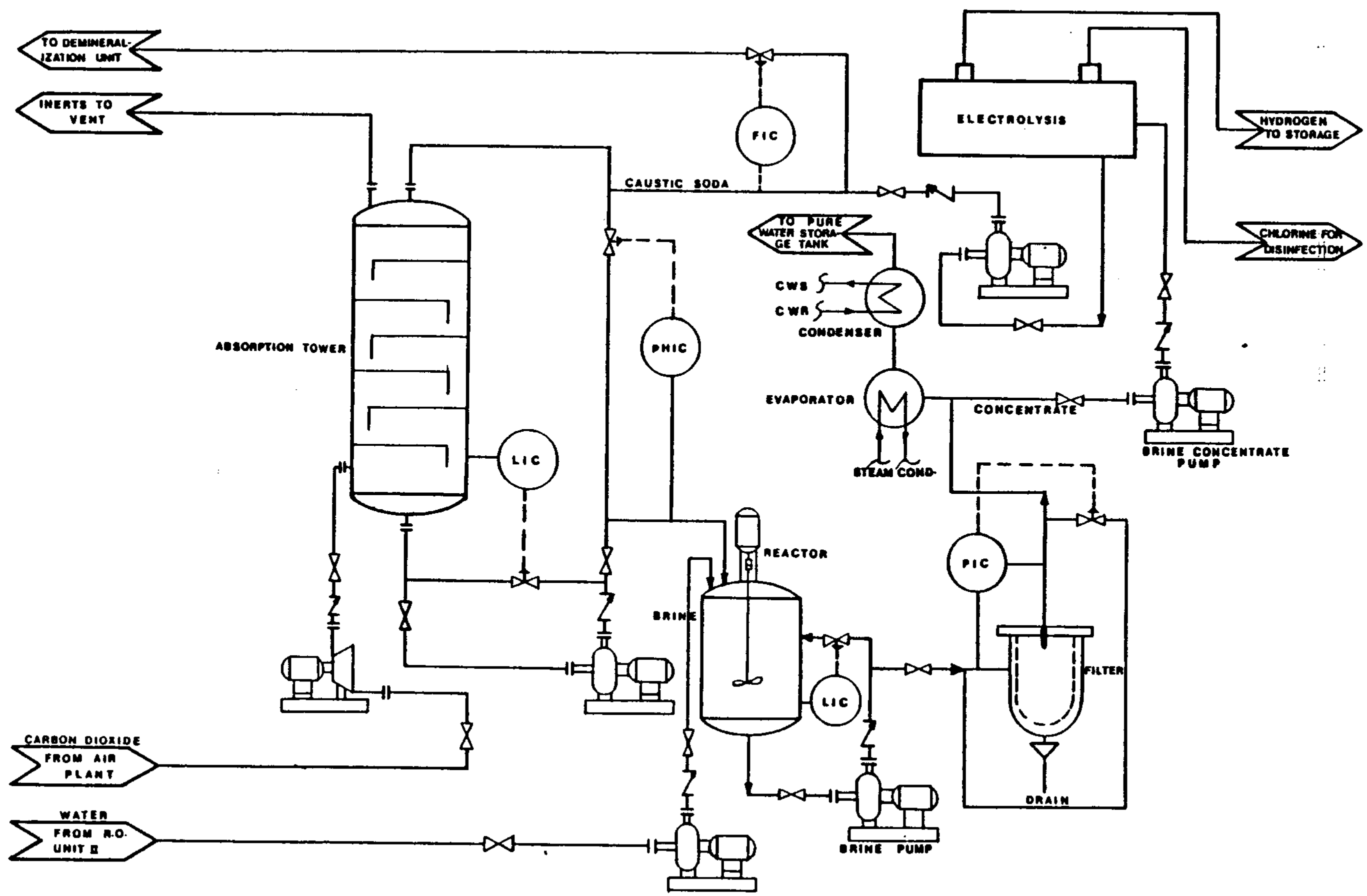
OVERALL REACTION

$$NaCl(aq) + H_2O(l) \longrightarrow NaOH(aq) + 1/2H_2(g) + 1/2\ Cl(g)$$

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH

5

DISINFECTANT MANUFACTURING UNIT



PVAM

NASA/USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

Thus;CATION EXCHANGE

$$\begin{matrix} Mg^{++} \\ Na^{+} \end{matrix} \begin{matrix} HCO_3^- \\ Cl^- \end{matrix} + 2HZ = \begin{matrix} Mg^{++} \\ Na^{+} \end{matrix} Z + H^+ \begin{matrix} HCO_3^- \\ Cl^- \end{matrix}$$

Regeneration

$$\begin{matrix} Mg^{++} \\ Na^{+} \end{matrix} Z + 2HNO_3 = 2HZ + \begin{matrix} Mg^{++} \\ Na^{+} \end{matrix} NO_3^-$$

ANION EXCHANGE

$$H^+ \begin{matrix} Cl^- \\ HCO_3^- \end{matrix} + RNH_3.OH = RNH_3 \begin{matrix} Cl^- \\ HCO_3^- \end{matrix} + H_2O$$

Regeneration

$$RNH_3 \begin{matrix} Cl^- \\ HCO_3^- \end{matrix} + NaOH \dashrightarrow RNH_3.OH + Na^+ \begin{matrix} Cl^- \\ HCO_3^- \end{matrix}$$

ORIGINAL PAGE IS
OF POOR QUALITY

Technical Data Sheet

DOWEX HGR-W Resin

Principal Uses: Best suited for industrial service, such as hot lime zeolite, demineralizing and mixed bed systems. Also for low concentration chrome treatment. Longer life under severe operating conditions and when oxidizing agents are present. Operating temperature to 250°F. (121°C)

General Description: A transparent, water-white cation exchanger produced from a sulfonated copolymer of styrene and divinylbenzene. Strainfree, spheroidal form permits use under conditions restricting application of standard cation exchange resins. Slightly greater density than DOWEX HCR-W.

Density (approx)	54 lb per cu ft (Na Form)
Specific Gravity (true density)	1.30 (Na Form)
Moisture Content (approx)	40-43% (Na Form)
Void Volume (approx)	3.0 gal per cu ft
Wet Mesh Size	Principally 16-40 mesh

Note—Sales Specifications available from Dow Sales Offices.

Regeneration: With sodium chloride (NaCl) at dosages of 6 lb to 15 lb per cu ft for water softening. With either sulfuric or hydrochloric acid for hydrogen cycle use.

Operating Flow Rate: 6 gpm per sq ft for 36 in beds, 2.0 gpm per cu ft for shallower beds; 30 in beds recommended as minimum.

Capacity Range:

Lb NaCl per cu ft (water softening)	Capacity, kgr per cu ft as $CaCO_3$ (dependent on TDS)
6	23—26
10	28—32
15	30—35

Bed Expansion: 50% max.
@ 9 gpm/ft²
@ 25°C

T.D. Index 140.01 contains operational data applicable to DOWEX HGR-W resin.

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

Table 1: Impact of common foulants on resin

Foulant	Cause	Impact
CATION RESIN		
Calcium	Precipitation of calcium sulfate; poor regeneration	Reduced capacity; hardness leakage
Magnesium	Poor regeneration	Reduced capacity; hardness leakage
Iron	In soluble form, is exchanged during service cycle and may then be oxidized and deposited on and within resin beads	Reduced capacity; resin cracking or fragmentation; iron leakage
Aluminum	Exchanged during service cycle but does not elute well during regeneration	Reduced capacity
Barium	Exchanged during service cycle but does not elute well during regeneration. Also, precipitates during sulfuric acid regeneration	Reduced capacity
Silica	Silt in influent	Reduced capacity; poor quality
Oil/grease	Oil-lubricated pumps	Reduced capacity; poor quality
ANION RESIN		
Organics	High ratio of TOC to total anions	Reduced strong-base-resin capacity; poor quality; short service runs; shortened life
Iron	Precipitation	Shortened life; reduced capacity
Silica	Inadequate regeneration caused by concentration of caustic and low caustic temperature	Short runs, poor quality
Aluminum	Precipitation	Reduced capacity; shortened life
Suspended matter	Precipitation	Reduced capacity; poor quality
Oil/grease	Oil-lubricated pumps	Reduced capacity; poor quality

Capacity and Rinse Requirements

of DOWEX MWA-1 resin

EXHAUSTANT 250 ppm TOTAL ACID	FLOW RATE gpm/ft³	REGENERANT DOSAGE lb/ft³	TEMPERATURE °F	RINSE REQUIREMENTS gal/ft³ to .1M Ω	CAPACITY kgr/ft³ to 20,000 Ω
		NaOH			
HCl/H_2SO_4	6	7	77 (25 C)	15	22.7
HCl/H_2SO_4	6	5	77	19	22.8
HCl/H_2SO_4	6	3	77	22	21.3
HCl	6	5	77	17	22.2
HNO_3	6	5	77	15	24.3
H_2SO_4	6	5	77	20	22.8
HCl/H_2SO_4	6	5	54 (12 C)	22	20.3
HCl	6	5	54	17	20.3
H_2SO_4	6	5	54	22	21.9
HCl/H_2SO_4	3	5	77 (25 C)	16	23.1
HCl/H_2SO_4	4.5	5	77	17	22.9
HCl/H_2SO_4	9.0	5	77	16	22.9
HCl/H_2SO_4	6	NH_4OH	77	22	20.0
HNO_3	6	4.35	77	22	22.4
		Na_2CO_3			
HCl/H_2SO_4	6	6.6	77	25	19.6

Technical Data Sheet

DOWEX SBR-P Resin

Principal Uses: A highly porous anion exchanger for use in all types of deionizers, performing best on waters having a high percentage of weak acids (CO_2 and SiO_2) to total anions. Also used in ion exchange waste treatment processes. Operating temperature below 120°F, (49°C).

General Description: A styrene type, strongly basic anion exchanger produced from styrene and divinylbenzene, and containing quaternary ammonium groups; spherical form.

Density (chloride form) (approx)	43 lb per cu ft
Specific Gravity (true density)	1.09
Moisture Content	53 - 60%
Void Volume (approx)	3.0 gal per cu ft
Mesh Size	Principally 16-40 mesh

Note — Sales Specifications available from Dow Sales Offices.

Regeneration: With sodium hydroxide (NaOH) at dosages of 3.5 lb per cu ft or higher, at temperatures ranging from 75°F (24°C) to 120°F (49°C).

Operating Flow Rate: 6 gpm per sq ft for 36 in beds, 2.0 gpm per cu ft for shallower beds; 30 in beds recommended as minimum.

Capacity Range:

lb NaOH per cu ft	kgr per cu ft as $CaCO_3$ Acid removing capacity ($HCl : H_2SO_4$)
3.5	9.0 — 9.5
5.0	11 — 11.5
7.5	12.5 — 13

Bed Expansion: 80% max.
@ 4 gpm/ft²
@ 25°C

112 *For further Information — see T.D. Index 230.01*

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. POTOUE
PAGE:

How Impurities in Water Are Expressed

In the U.S., impurities are usually expressed in terms of calcium carbonate ($CaCO_3$) as grains per gallon (gpg), equivalents per million (epm), or parts per million (ppm). Foreign systems expressing impurities are:

1 English degree (°Clark) = 1 grain $CaCO_3$ per British Imperial gallon water.
1 French degree = 1 part $CaCO_3$ per 100,000 parts water.
1 German degree = 1 part Calcium Oxide (CaO) per 100,000 parts water.

CONVERSIONS BETWEEN SYSTEMS

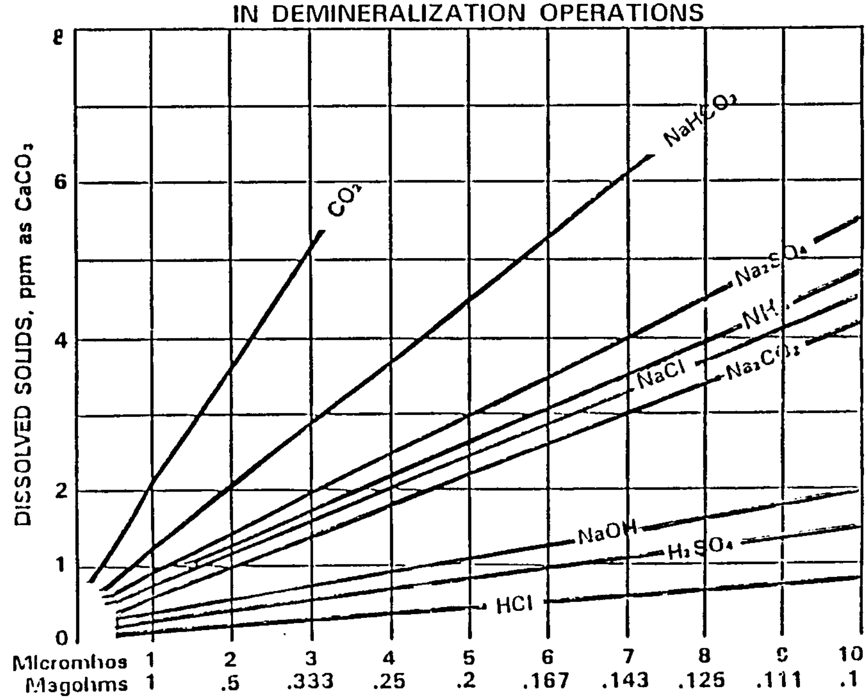
	Grains per U.S. Gallon (gpg)	Parts per Million (ppm)	Equiv. per Million* (epm)	English Degrees (Clark)	Parts per 100,000 (French Degrees)	German Degrees
1 grain per U.S. gallon	1.0	17.1	.343	1.2	1.71	.958
1 part per 100,000	.583	10.0	0.2	0.7	1.0	0.56
1 part per million	.058	1.0	.02	.07	0.1	.056
1 equivalent per million*	2.92	50.0	1.0	3.5	5.0	2.8
1 English Degree (°Clark)	.833	14.3	.286	1.0	1.43	0.8
1 French Degree	.583	10.0	0.2	0.7	1.0	0.56
1 German Degree	1.04	17.9	.357	1.24	1.79	1.0

*1 equivalent per million = 1 milli-equivalent per liter.

CONVERSION FACTOR USED IN ION EXCHANGE

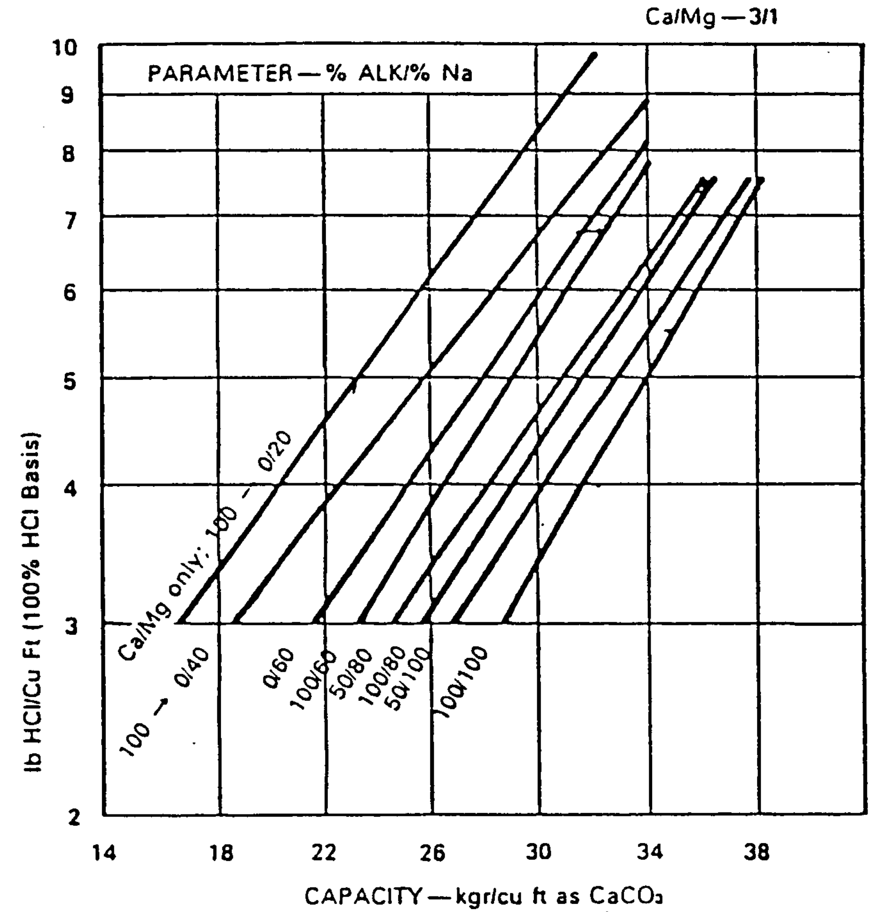
Ion	Factor		Ion	Factor	
Ca	X 2.5	= $CaCO_3$	NO_3	X .81	= $CaCO_3$
Mg	X 4.1	= $CaCO_3$	HCO_3	X .82	= $CaCO_3$
Na	X 2.18	= $CaCO_3$	PO_4	X 1.56	= $CaCO_3$
K	X 1.28	= $CaCO_3$	*CO_3	X .84	= $CaCO_3$
SO_4	X 1.04	= $CaCO_3$	*CO_2	X 1.14	= $CaCO_3$
Cl	X 1.41	= $CaCO_3$	*SiO_2	X .83	= $CaCO_3$

RELATIONSHIP BETWEEN
DISSOLVED SOLIDS AND CONDUCTANCE
IN DEMINERALIZATION OPERATIONS



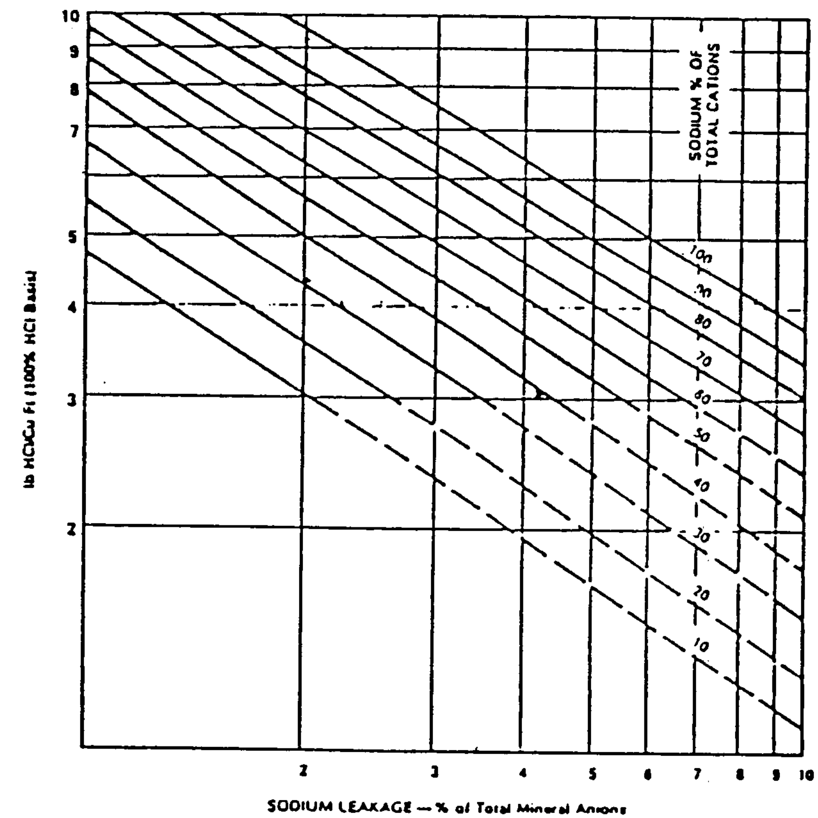
NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

Capacity Rating of DOWEX Cation Exchangers
Corrected for Leakage



	NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. POTOUH PAGE:

Sodium Leakage from HCl Regenerated DOWEX Cation Exchange Resins



NASA / USRA

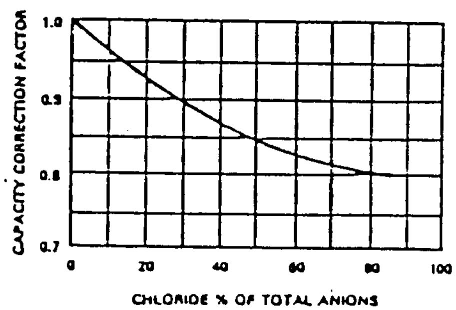
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

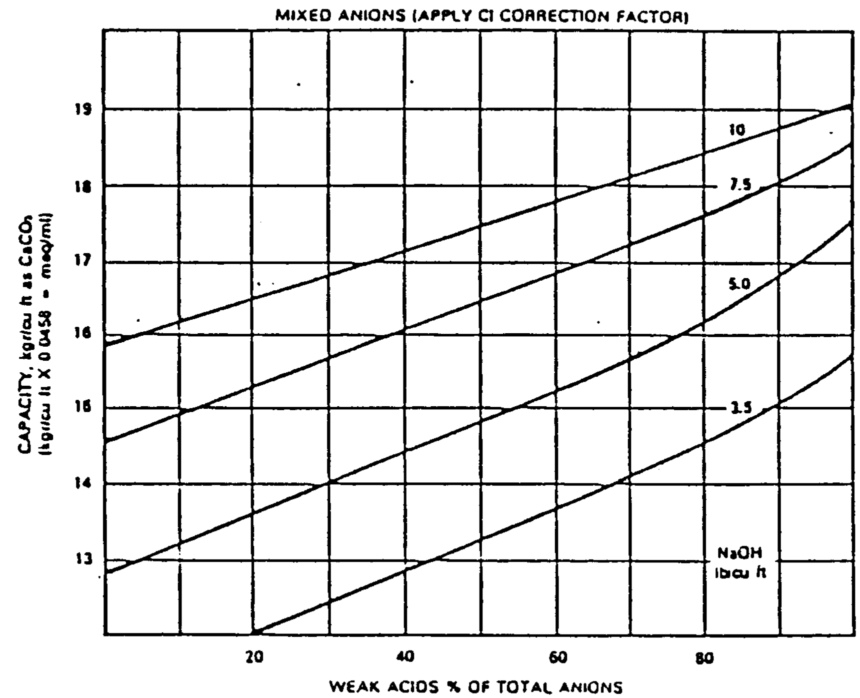
APPROVED BY: K. FOTOUH

PAGE:



Operating Exchange Capacity of DOWEX SBR-P Resin

(120 F (49 C) Regenerating Temperature, 77 F (25 C) Operating Temperature



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

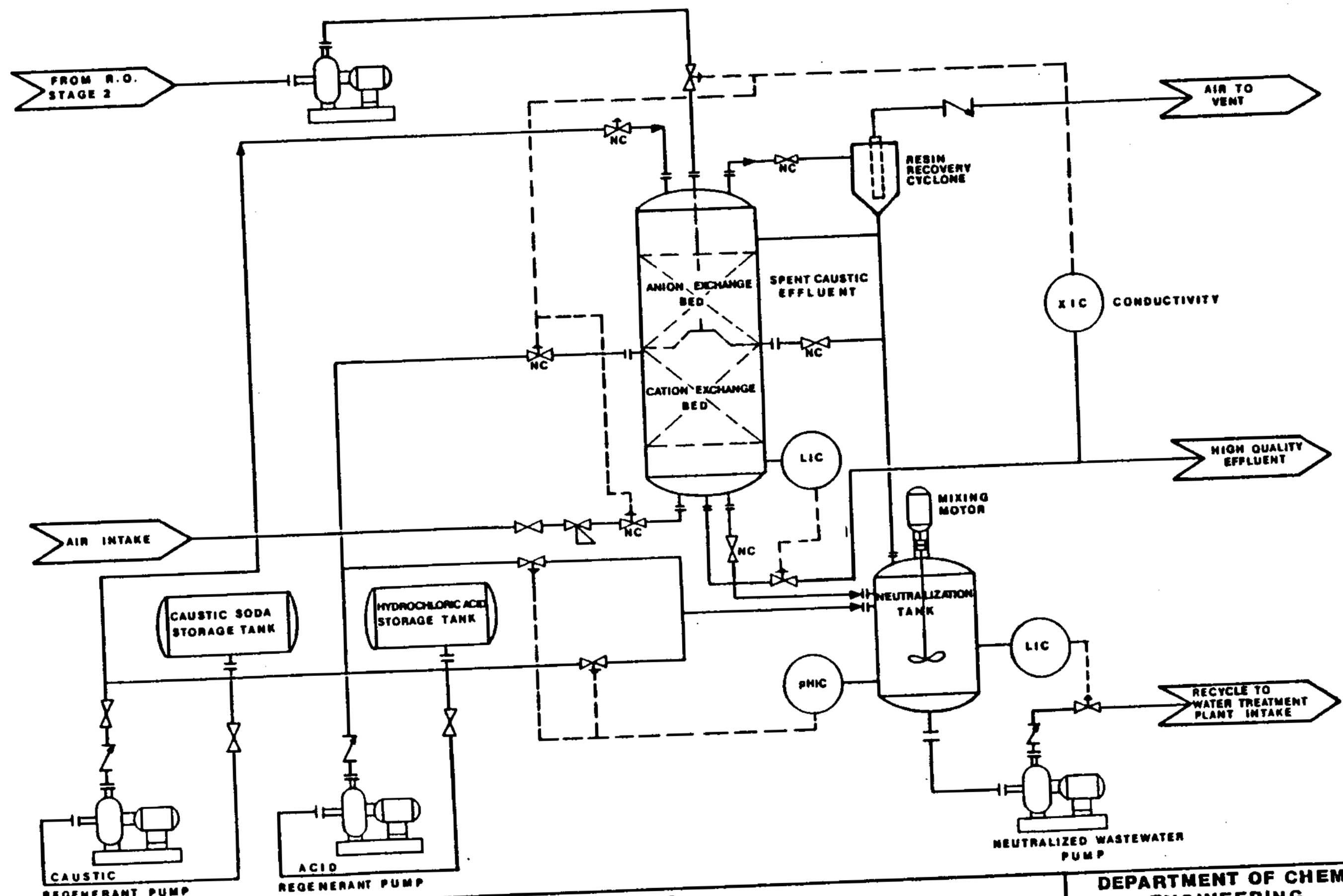
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. POTOUH

PAGE:

6 DEMINERALIZATION UNIT



NASA/USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

ORIGINAL PAGE IS
OF POOR QUALITY

WASTEWATER CONSTITUENTS

Characteristic	Sources
Physical properties:	
Color	Domestic and industrial wastes, natural decay of organic materials
Odor	Decomposing wastewater, industrial wastes
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, inflow-infiltration
Temperature	Domestic and industrial wastes
Chemical constituents:	
Organic:	
Carbohydrates	Domestic, commercial, and industrial wastes
Fats, oils, and grease	Domestic, commercial, and industrial wastes
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic and commercial wastes
Surfactants	Domestic and industrial wastes
Others	Natural decay of organic materials
Inorganic:	
Alkalinity	Domestic wastes, domestic water supply, groundwater infiltration
Chlorides	Domestic water supply, domestic wastes, groundwater infiltration, water softeners
Heavy metals	Industrial wastes
Nitrogen	Domestic and agricultural wastes
pH	Industrial wastes
Phosphorus	Domestic and industrial wastes, natural runoff
Sulfur	Domestic water supply, domestic and industrial wastes
Toxic compounds	Industrial wastes
Gases:	
Hydrogen sulfide	Decomposition of domestic wastes
Methane	Decomposition of domestic wastes
Oxygen	Domestic water supply, surface-water infiltration
Biological constituents:	
Animals	Open watercourses and treatment plants
Plants	Open watercourses and treatment plants
Protista	Domestic wastes, treatment plants
Viruses	Domestic wastes

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUE
PAGE:

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DESIGN ASSUMPTIONS

Flowrate 10,000 gallons/day

Gravity = 3/8 earths gravity

Stokes law applies to settling

Return sludge concentration is 7000 mg/L

Temperature 20° C

WASTEWATER COMPOSITION

(Untreated Domestic Wastewater)

* All values except settleable solids are expressed in mg/L.

CONSTITUENT	* CONCENTRATION
SOLIDS, TOTAL	720
DISSOLVED	500
SUSPENDED	220
SETTLEABLE SOLIDS	10 mL/L
BOD (Biochemical Oxygen Demand)	220

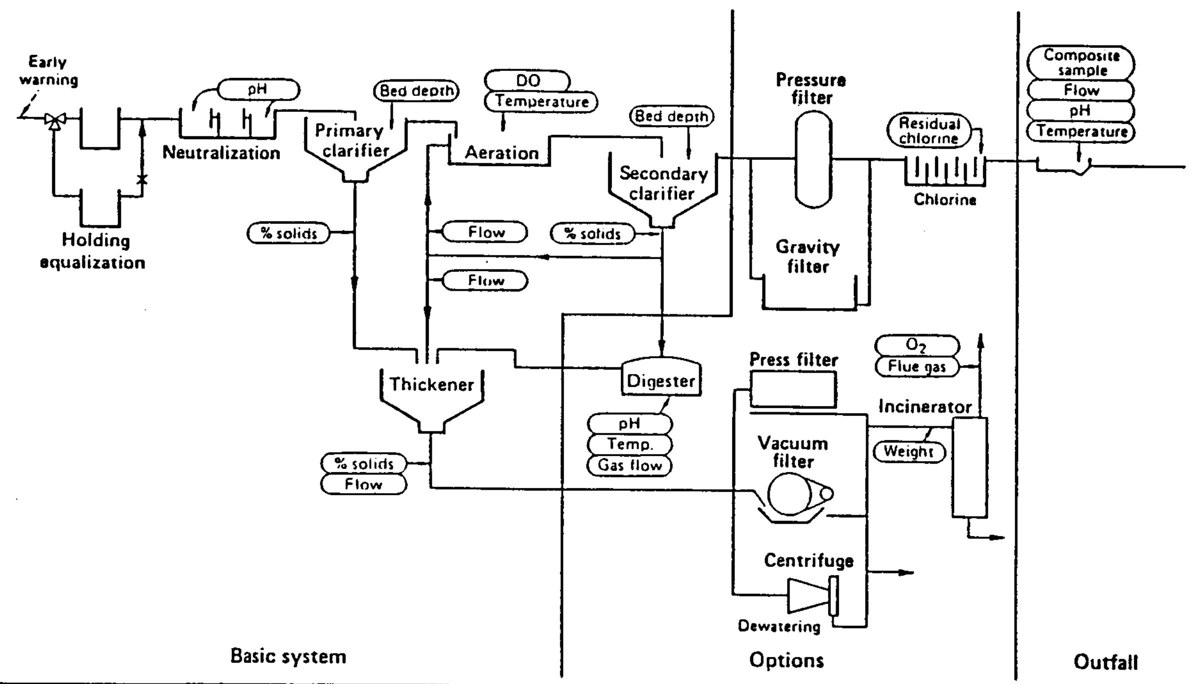
TEMPERATURE 20° C

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. POTOUH
PAGE:

EFFLUENT STANDARDS

CONSTITUTENT	CONCENTRATION
SUSPENDED SOLIDS	20 - 30 mg/L
BOD	15 - 25 mg/L



Typical wastewater treatment plant showing instrumentation described in text

NASA / USRA

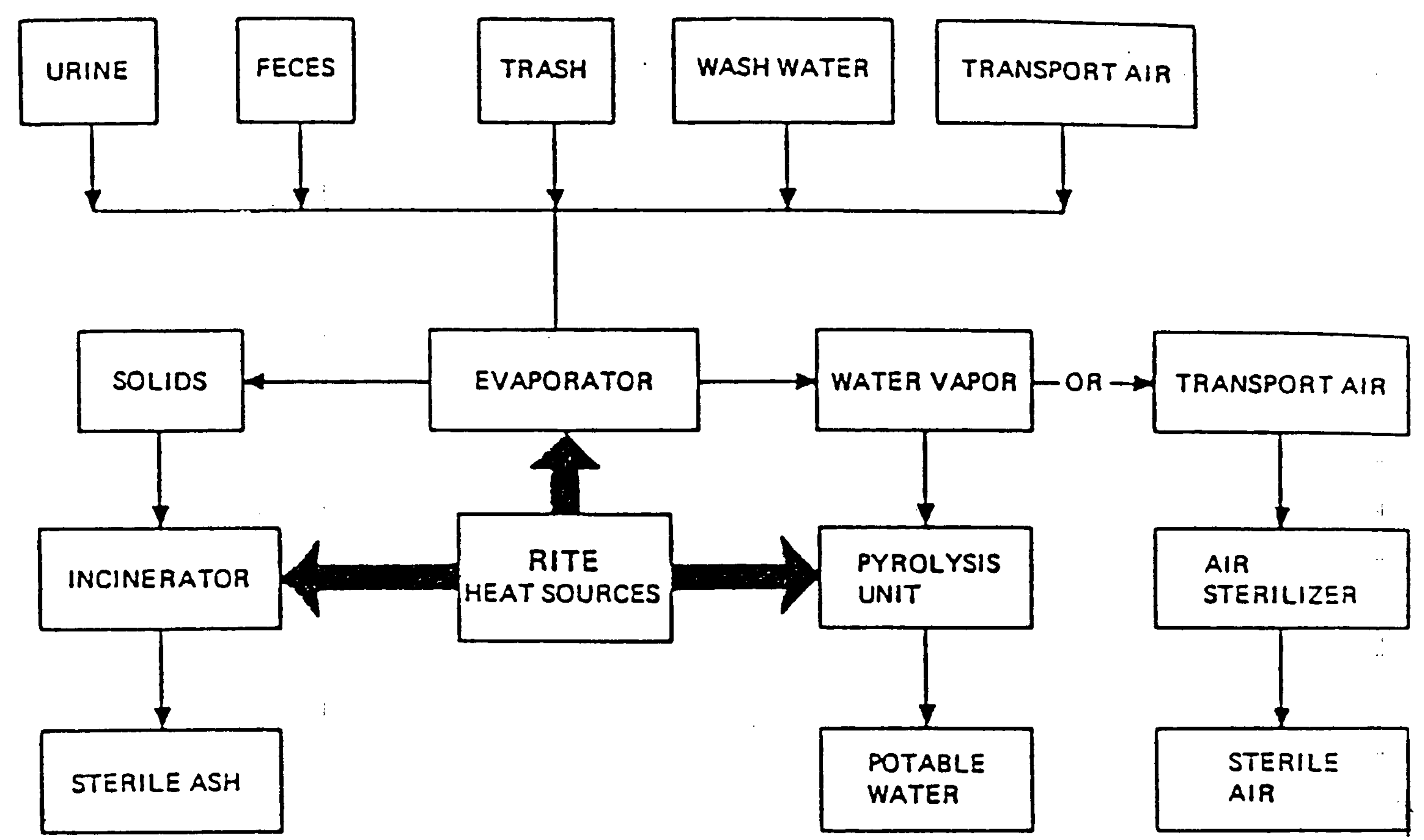
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

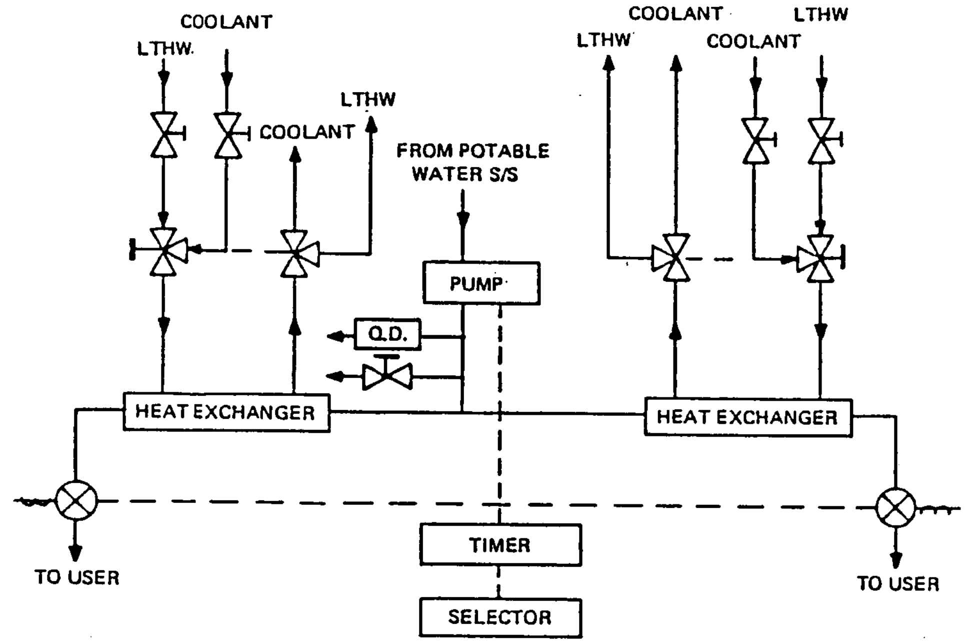
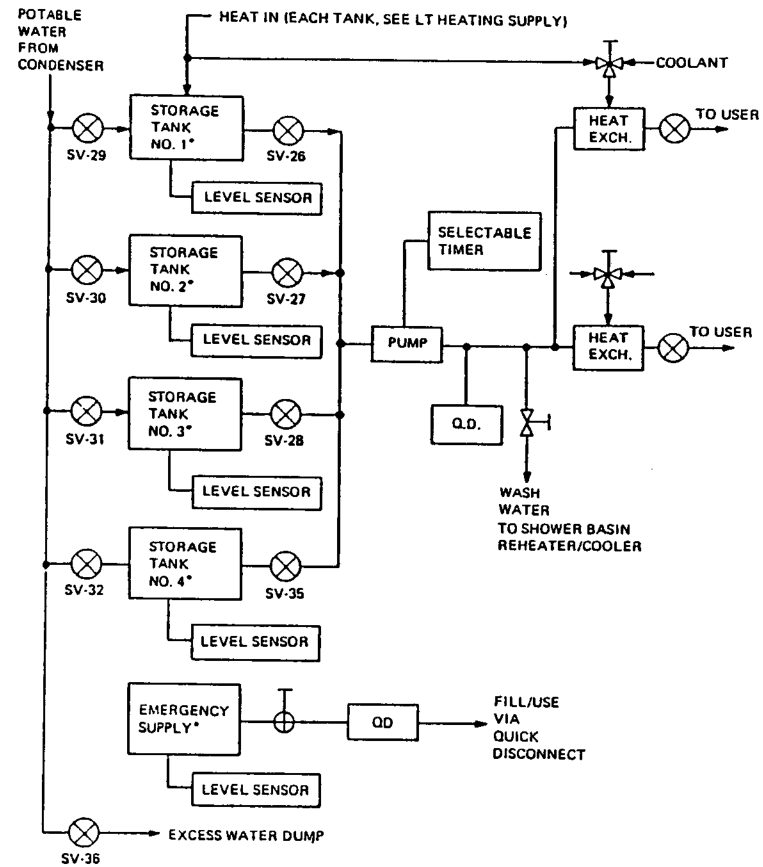


Figure Potable Water Dispensing Schematic

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH

PAGE:



*ELECTRIC HEATER PROVIDED IN EACH TANK FOR EMERGENCY STERILIZATION

Figure Potable Water Storage/Dispensing Functional Schematic

	NASA / USRA **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY

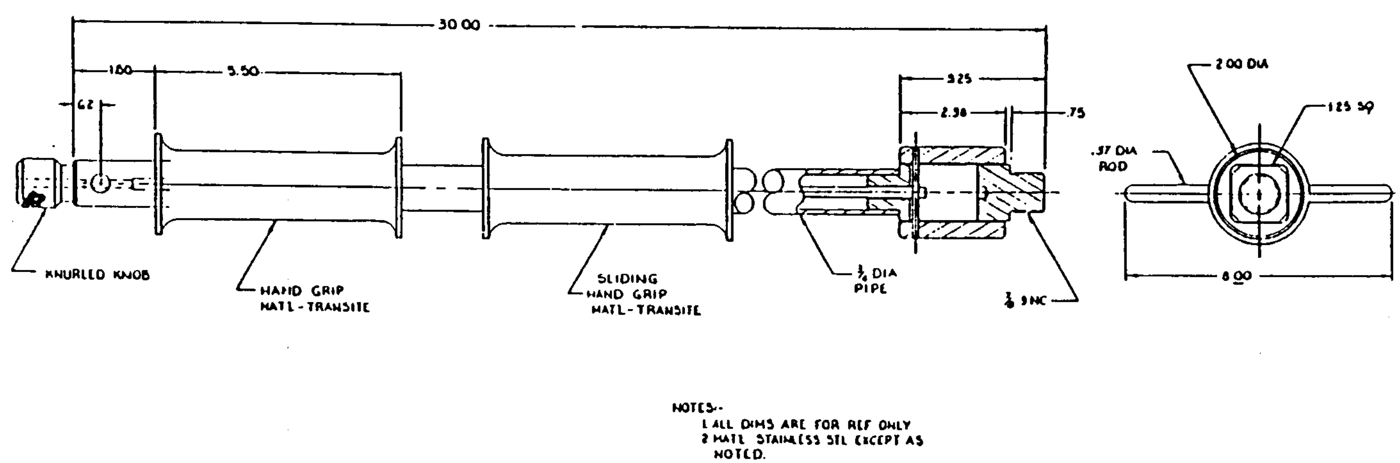


Figure Rite Heat Source Handling Device

PVAM	**NASA / USRA** **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

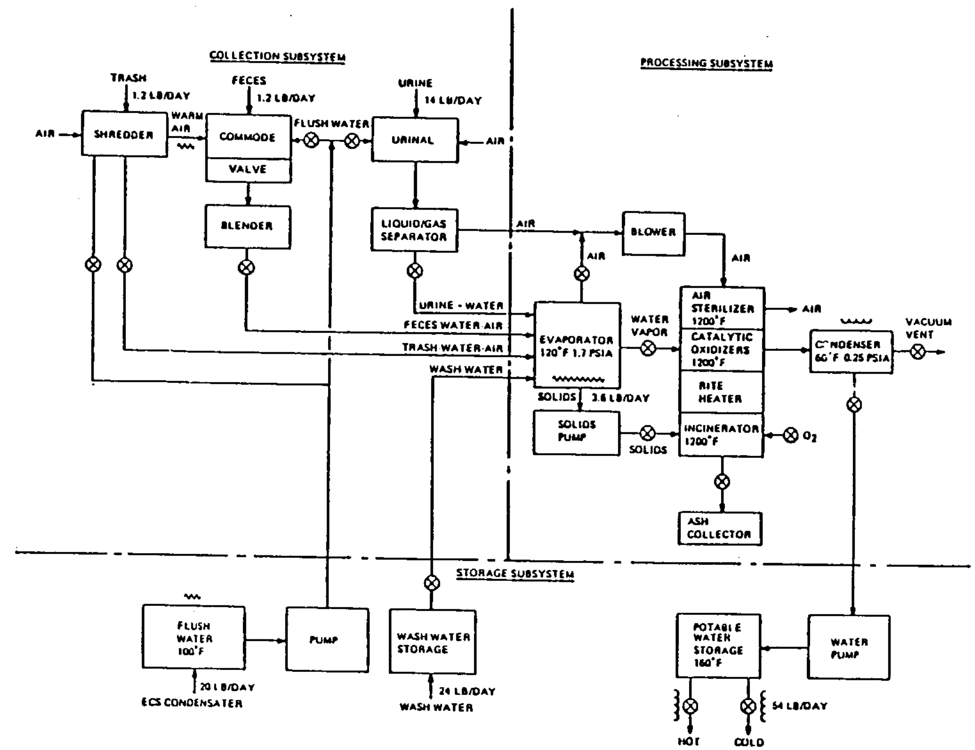


Figure WM-WS Functional Diagram

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

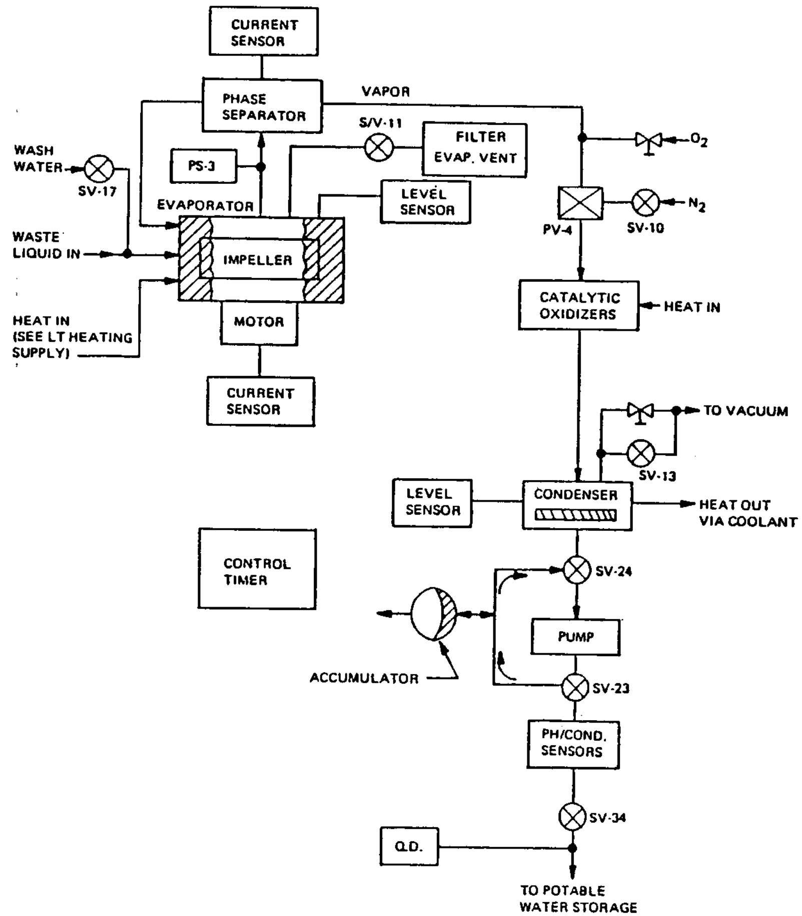


Figure Water Recovery Functional Schematic

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

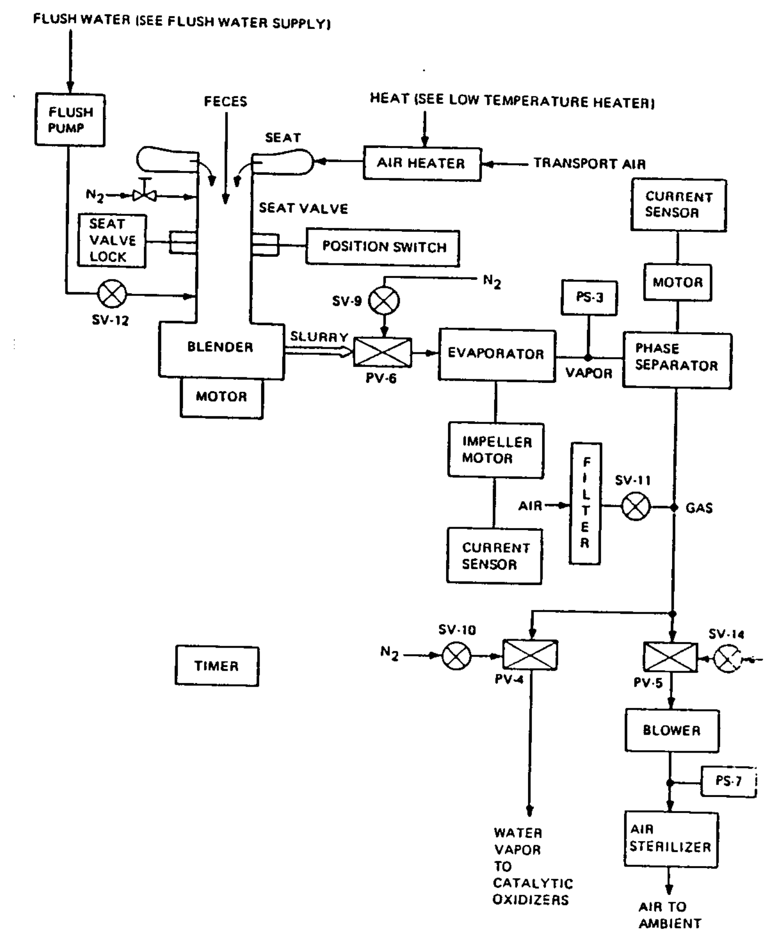


Figure Feces Collection Functional Schematic

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

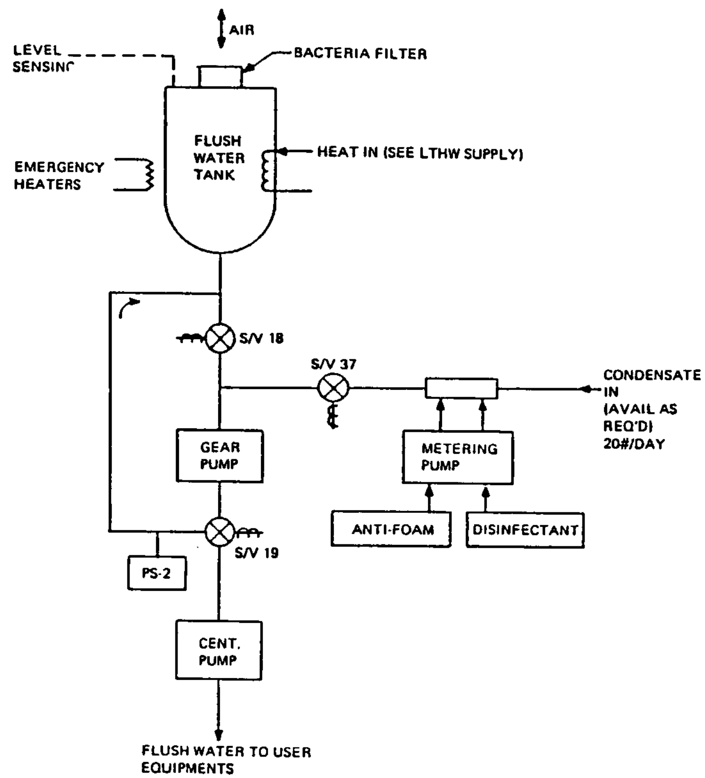


Figure Flush Water Supply Functional Schematic

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

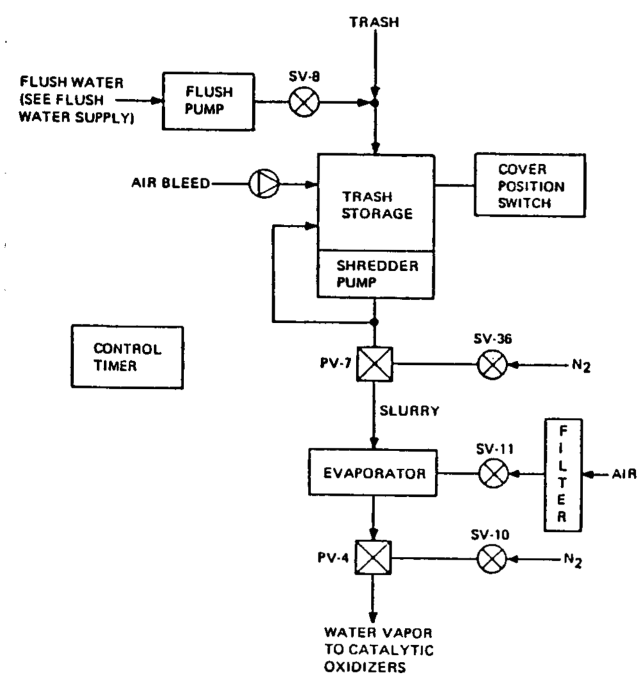


Figure Trash Collection Functional Schematic

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

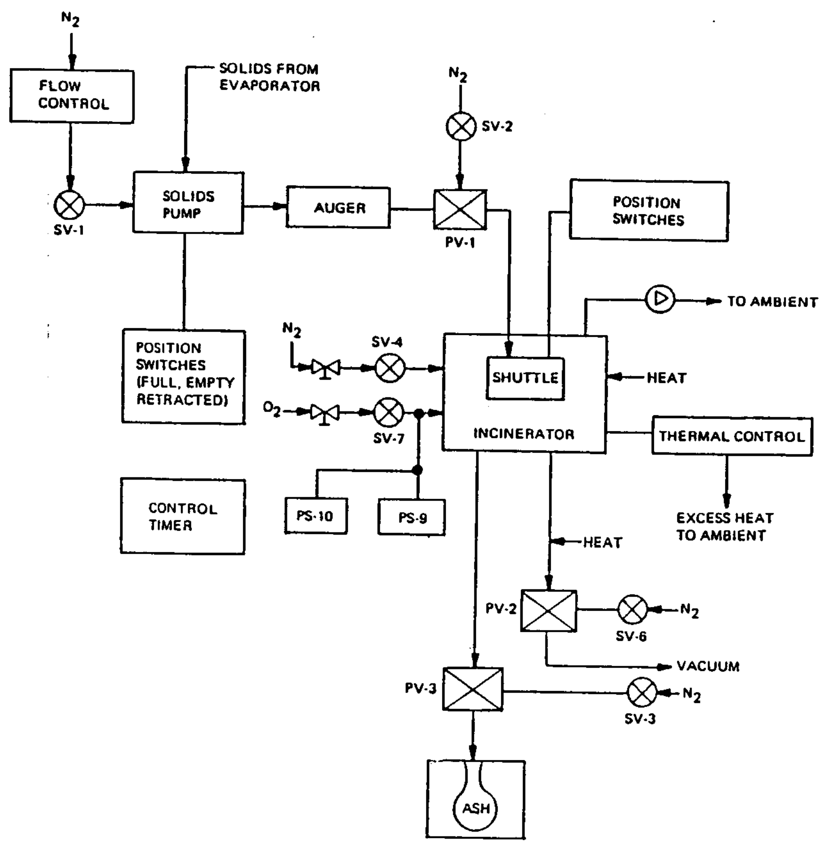


Figure Solids Pump and Incineration Functional Schematic

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

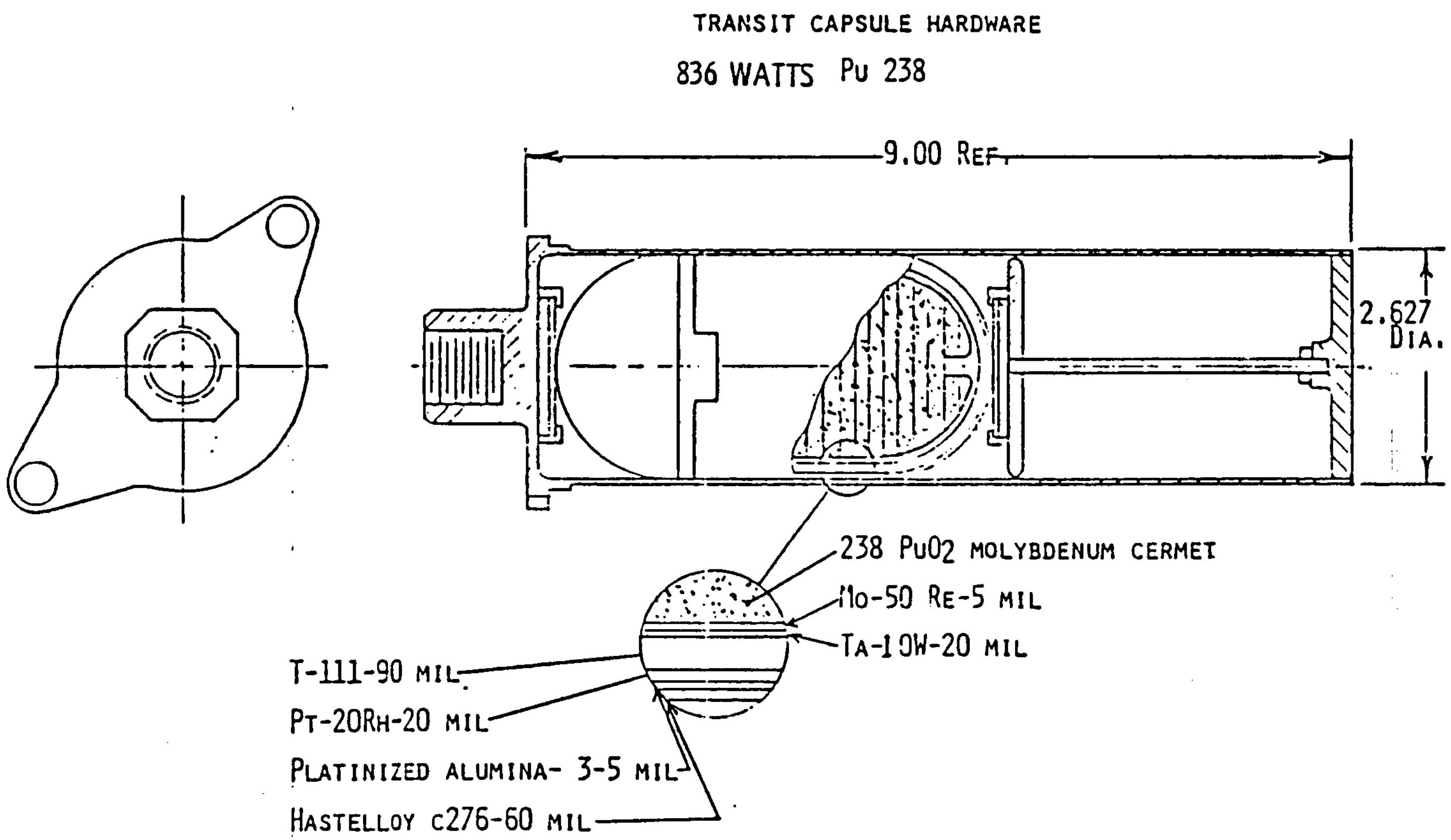


Figure Rite II Heat Source Layout Drawing

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

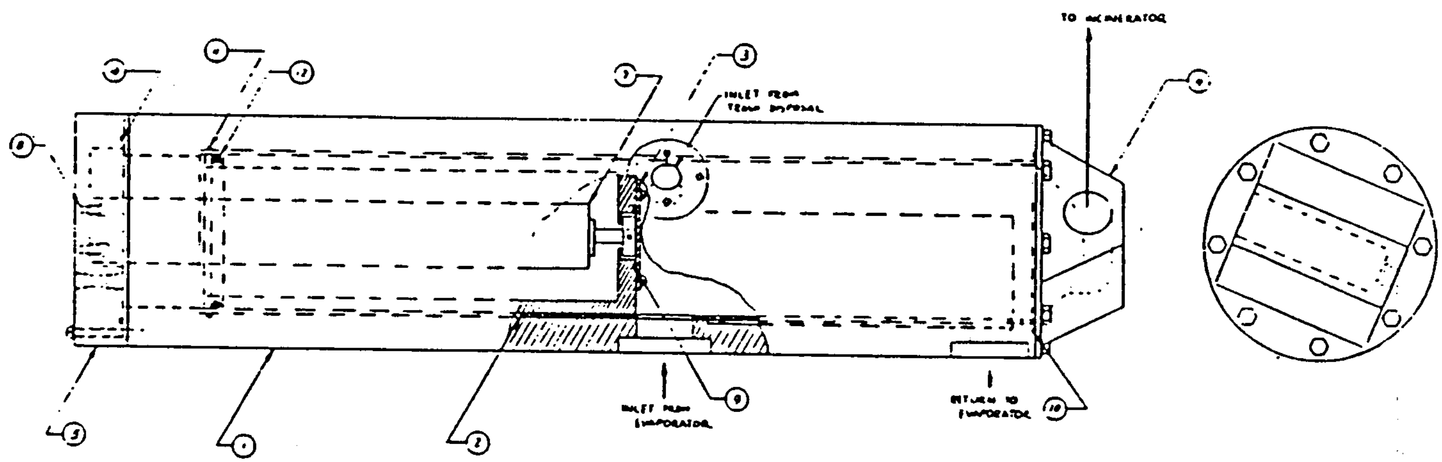


Figure Solids Pump

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

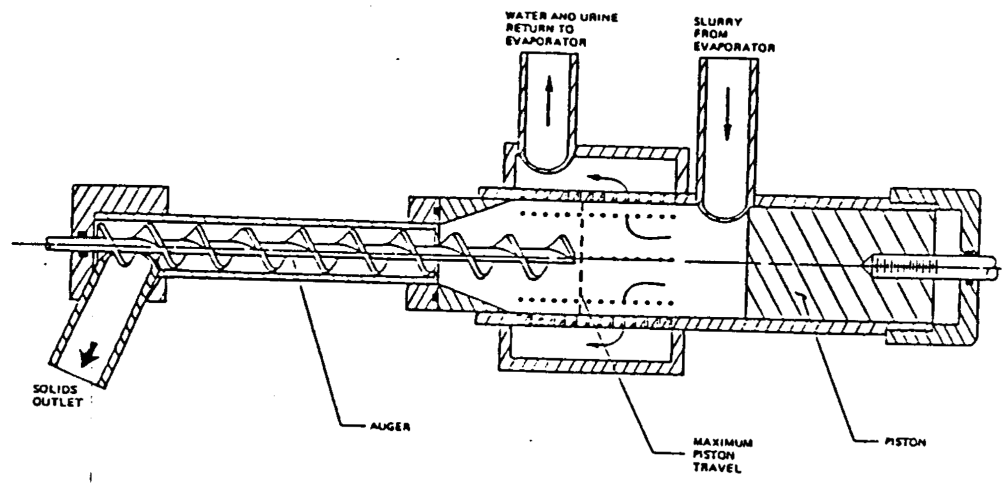


Figure Solids Pump Development Model with Auger, Schematic

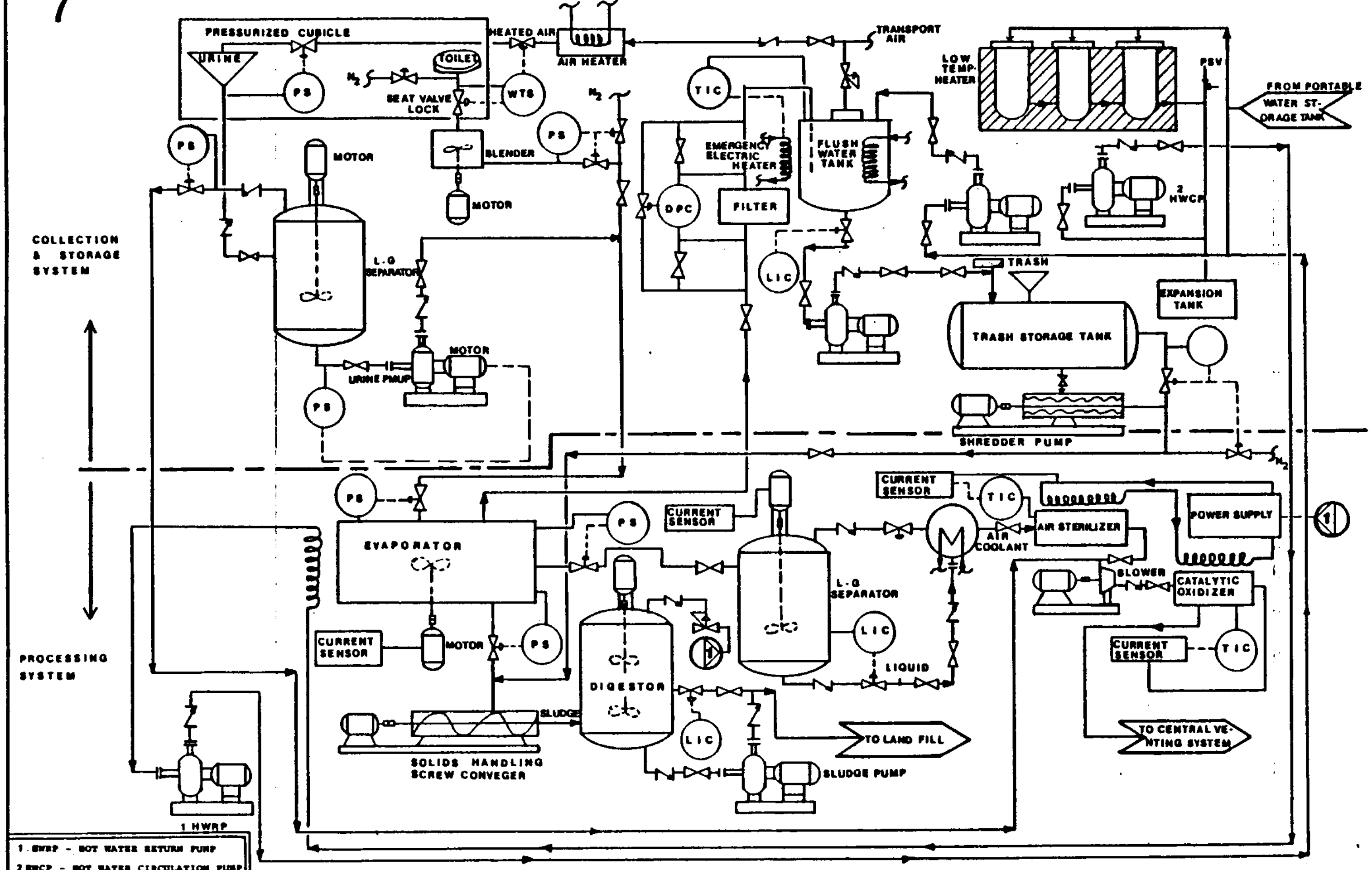
NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

7

DOMESTIC WASTE WATER MANAGEMENT



NASA/USRA

INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

K. FOTOUH

ADVANCED DESIGN PROJECT

COMPUTATION SHEET

PRAIRIE VIEW A&M UNIVERSITY
CHEMICAL ENGINEERING

Listed by	Project INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK I - B	Est. No.
Checked by	Client NASA/USRA	Sheet 2 of 2
Cont. No.	Location MARS	Date

SUMMARY OF TECHNIQUES FOR REMOVING METALS (CONTINUE)

Precipitation					
Thioacetamide		HCl	ppb (varies)	0.75 8.0	Cd,Cu,Pb Cr,Hg,Zn, Mn
Metal sulfides	Cooling tower blow-down	HCl	15-200 ppm	2.3	Cr,Mn,Sr, Cu,Ni,Co
Dibromo-oxine	Seawater	Acetone	ppb	8.0	Cu,Zn,Co, Mn,Pb,Cr
Potassium Ferrocyanide	Electroplating solutions	Activated carbon	-	-	Pb,Sn,Cd, Zn,Fe,Ni, Co
Dialkyldithio-carbamates	Process streams	–	70 ppm	4.2	Zn,Cu,Fe
Oxalate or sulfate	Radioactive rinse water	–	40 ppb	-	Sr
Polyelectrolytes	Process solvents	Polygalacturonic & alginic acids	mg/l	4.0-4.5	Cu,Cd,Zn, Ni, Cr
Aluminum sulfates	Industrial & municipal water	–	0.20 mg/l	6.8-7.0	Pb,Cu,Cr, Cd,Zn,Ni
Lime	Industrial & municipal water		0.26 mg/l	9.6	Mn & others
Carbonates	Industrial & municipal water	CaO or NaOH	0.2 mg/l	9.5	Mn & others
Hydroxides	a. Industrial & municipal water	$Ca(OH)_2$	100s of mg/l	>9.5	Pb,Cu,Cr, Ni,Co,Mn, Zn
	b. Seawater	$Ti(OH)_4$	24 μg/l	8.0	Mn
	c. Seawater	$Mg(OH)_2$	60 μg/l	-	Co
	d. Process solutions	$Mg(OH)_2 + Ca(OH)_2$	g/l	-	Sn,Pb
	e. Municipal & industrial water	NaOH	100s of mg/l	>9.5	Mn & others

ORIGINAL PAGE IS
OF POOR QUALITY

COMPUTATION SHEET

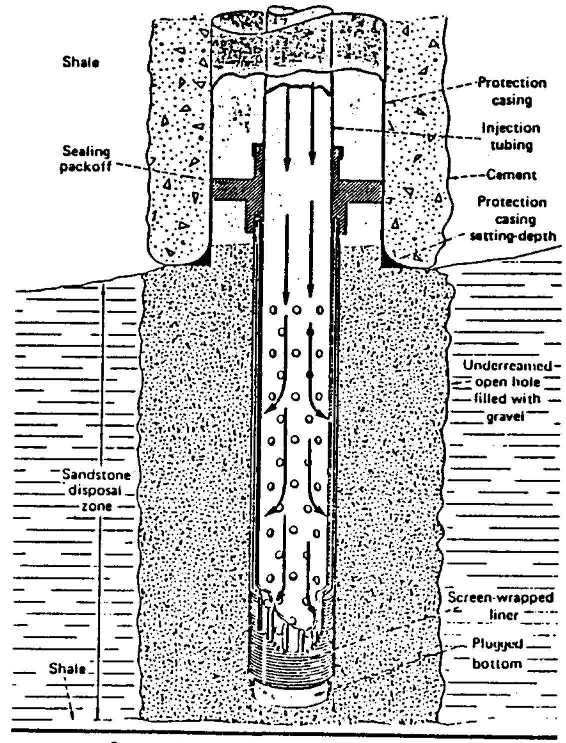
PRAIRIE VIEW A&M UNIVERSITY
CHEMICAL ENGINEERING

ORIGINAL PAGE IS OF POOR QUALITY

Listed by	Project INTEGRADTED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B	Est. No.
Checked by	Client NASA/USRA	Sheet 1 of 2
Cont. No.	Location MARS	Date

SUMMARY OF TECHNIQUES FOR REMOVING METALS

Method	Source	Reagents	Concentration	pH Range	Ions
Extraction	Water	Ammonium pyrrolidine dithiocarbamate, methyl iso butyl ketone, chloroform	Several ppb	4.5-6	Cu,Pb,Ni, Zn,Cd,Co, Mn,Mo,V
Foam separation	Industrial processes	N_2, surfactant	0.06 g/l & lower	5.5-6	Ni,Cr,Co, Sr
Autoclaving	Biological samples	Steam	ppb	–	Ti,Cr,Cu, Pb,Mn,Sn
Adsorption on alumina	Radioactive rinse water	–	Up to 1 x 10^{-3} moles/l	8.0	Sr
Aeration	Municipal & Industrial water supplies	$KMnO_4$, activated carbon	0.2 mg/l		Mn,Fe
Manganese zeolite bed	Municipal & Industrial water	$KMnO_4$, anthracite	0.2 mg/l	–	Mn,Fe
Ultraviolet radiation & magnetic field	Seawater, freshwater, industrial streams				All
Paper chromatographic separation	–	Mixture of chloroform, methanol, acetone, isopentanol & formic acid, TNOA HCl	ppb	–	Cu,Pb,Cd, Bi,Hg,Mn, Co,Ni,Cu, Zn,Fe
Rotating electrodes	Process streams, seawater	–	–	–	All
Biological	a. Acid mine waters	Yeasts, sulfur, glucose	10s of mg/l	3.5	Cu
	b. Municipal & Industrial water streams	Bacteria			Fe,Mn
Ion Exchange					
Chelex-100	Sea & fresh water, process waters	HCl	Varies	5-6	Cu,Pb,Cr, Ni,Zn,Co, Cd,Mn
Chitosan	Salt water	EDTA	ppb(varies)	--	Mn,Ti,Cr, Pb
Amberlite	Process liquid	Eluant	Varies	–	Cd,Co,Cu Pb,V,Zn, Ni
Titanium arsenate		NH_4NO_3 HNO$_3$	Varies	-	Pb,Cu,Cd, Sr,Zn,Mn, Ni,Co
Permutit-S1005	Seawater	Eluant	ppb	7.8 5.0(Mo,Cr) 6.0 (V) 9.0 (Mn)	Cd,Co,Cu, Pb,Ni,Zn Cr
DeAcidite FF + dibromo-oxine	Seawater, cooling tower blowdown	HCl or H_2SO_4	ppb 200 ppm	–	Co,Zn,Cr
Zeo-Karb 225	Process streams, rain water	H_2SO_4	ppb		Sr
Dowex	Water, process streams	Eluant	100 ppm	Varies	Ti,Sr,Mn Cd,Cr,Cu, Zn,Pb



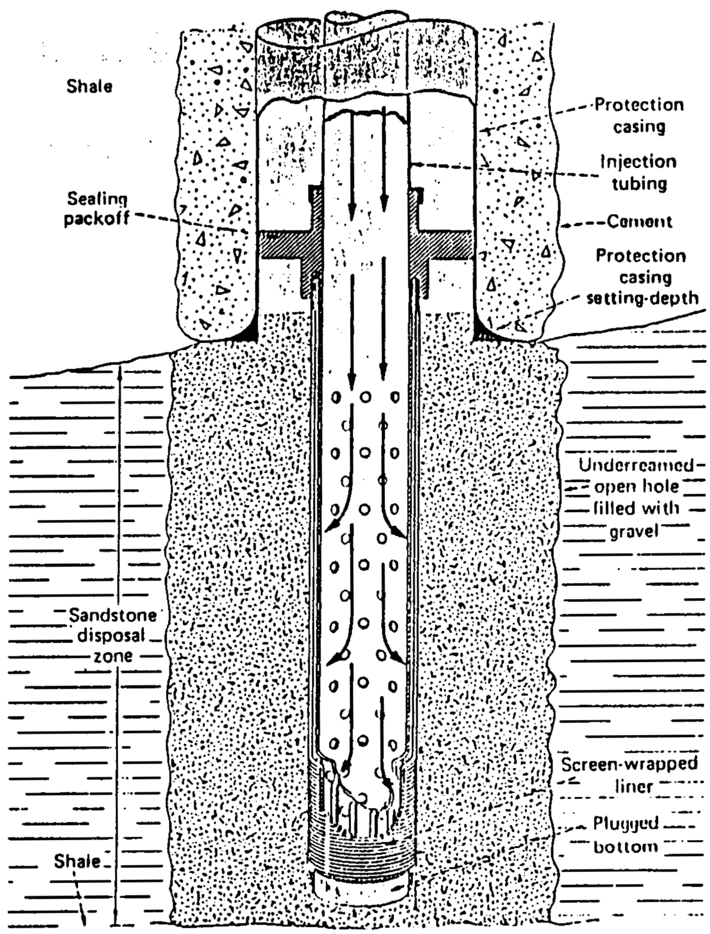
Completion for disposal into sandstone formation

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY



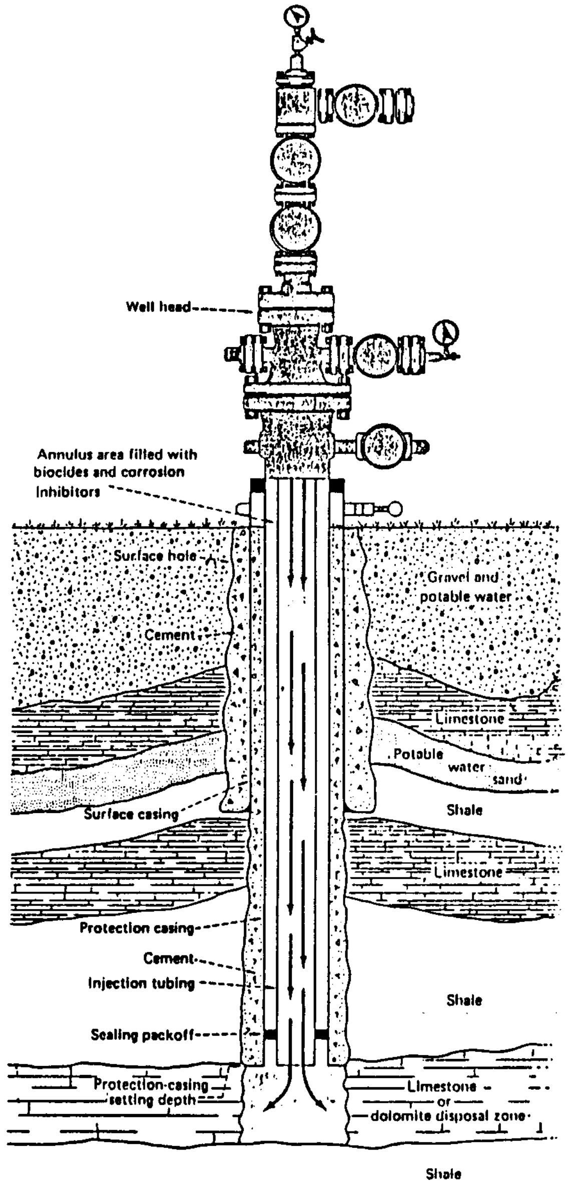
Completion for disposal into sandstone formation

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

ORIGINAL PAGE IS
OF POOR QUALITY



Well casing and completion for deepwell disposal into limestone or dolomite

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

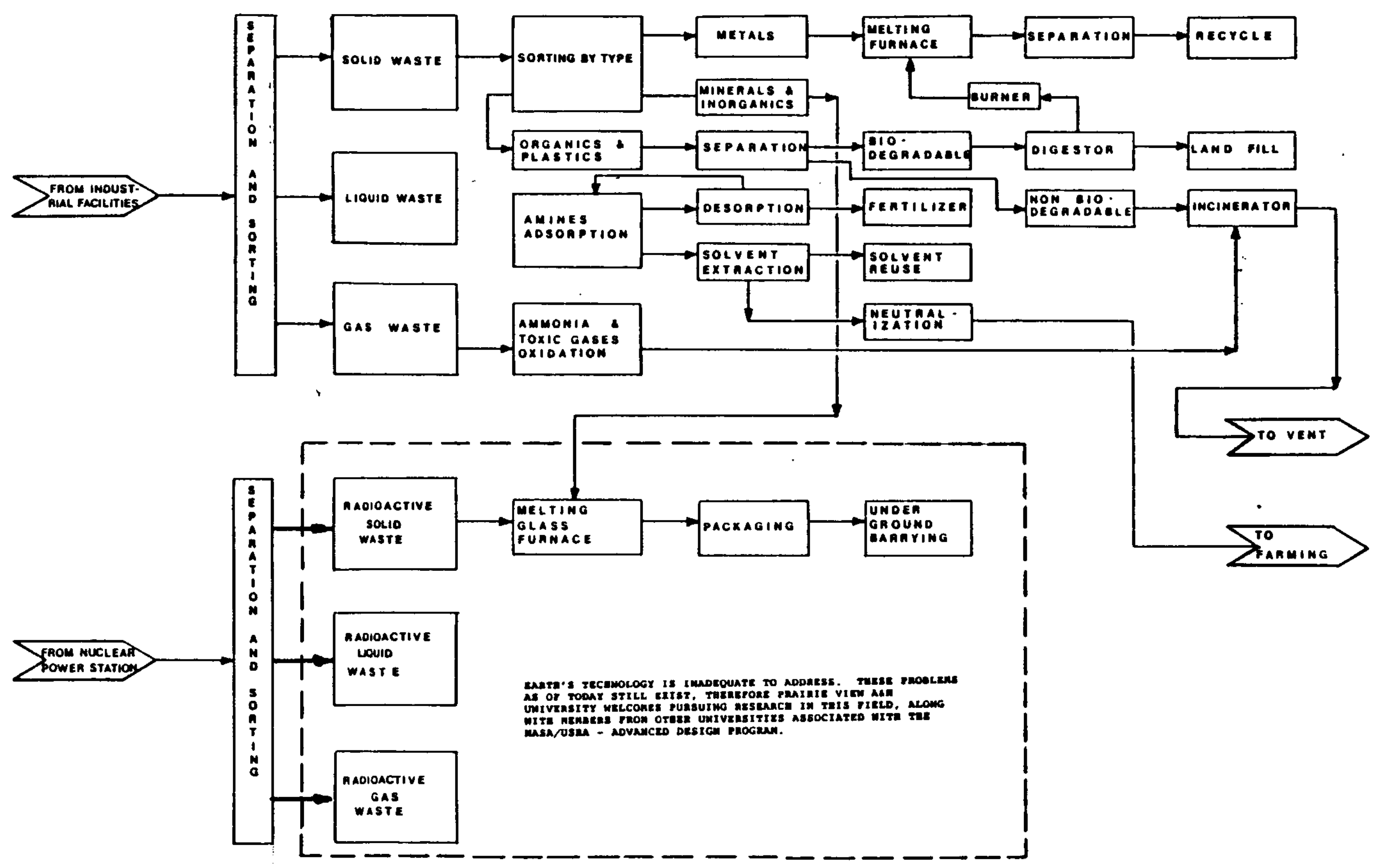
PAGE:

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

ORIGINAL PAGE IS
OF POOR QUALITY

8 HYPOTHETICAL INDUSTRIAL WASTE MANAGEMENT SCHEME



NASA/USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

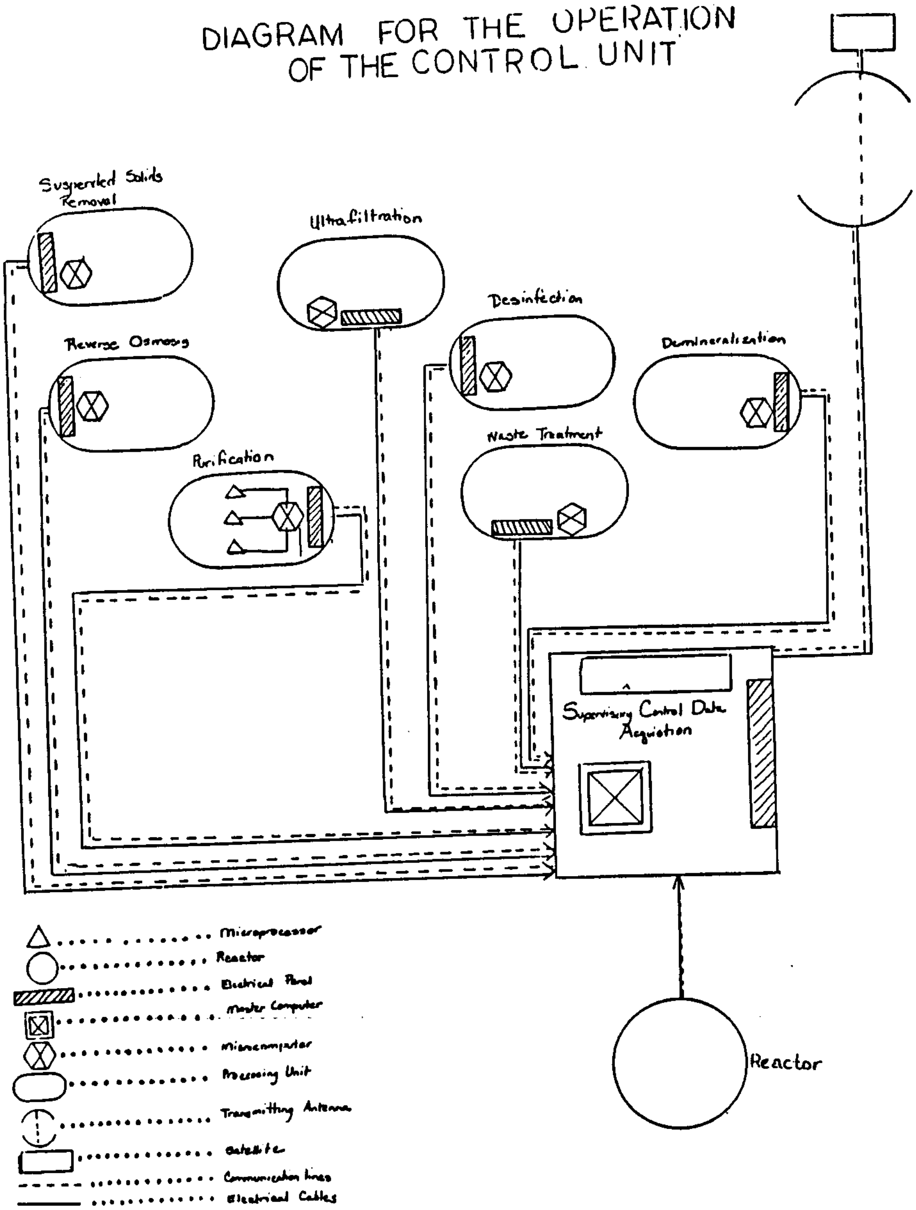
K. FOTOUH

ADVANCED DESIGN PROJECT

C-2

ORIGINAL PAGE IS
OF POOR QUALITY

DIAGRAM FOR THE OPERATION OF THE CONTROL UNIT



DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH

PAGE:

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

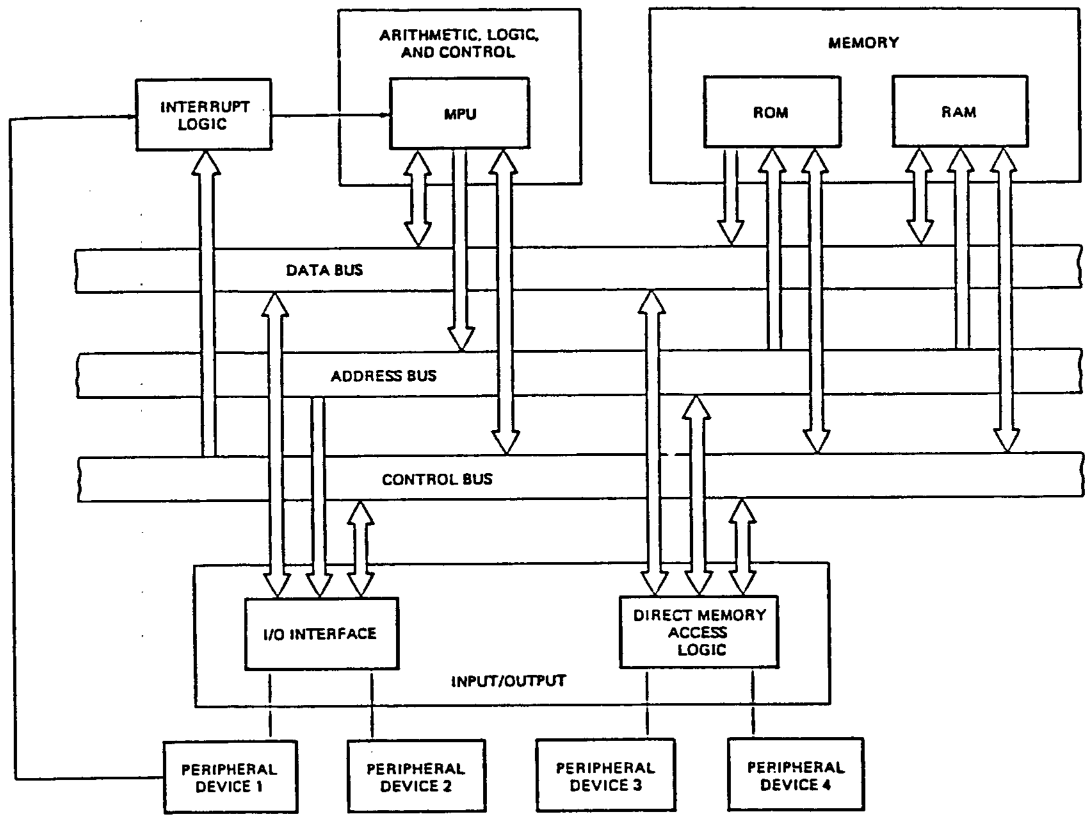
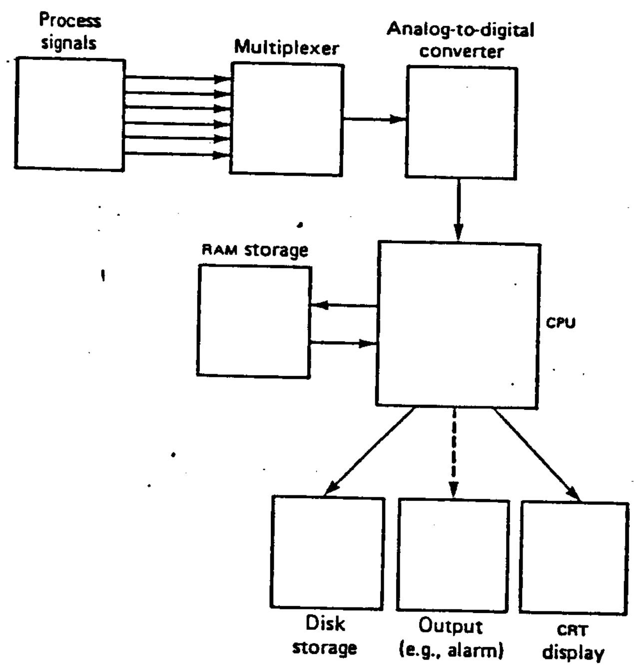


Figure · Architecture of a Typical Microcomputer.

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:



How data move through the monitoring system

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

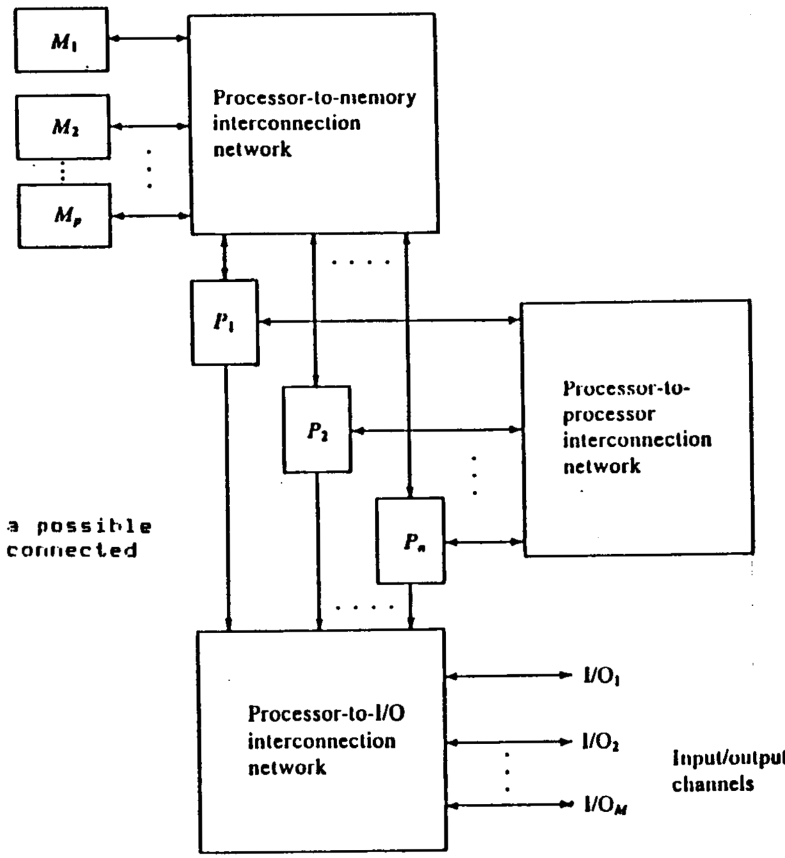
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

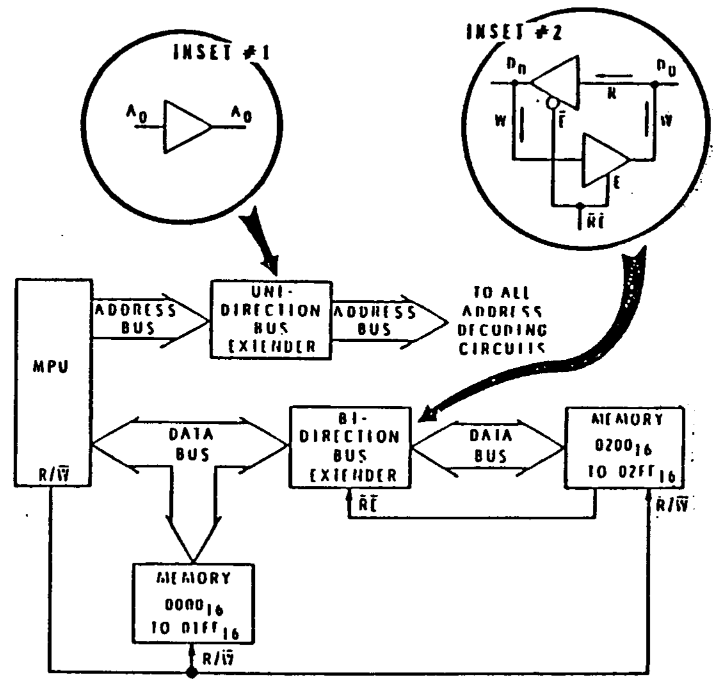
ORIGINAL PAGE IS
OF POOR QUALITY



A simple diagram basically showing a possible way to have several microprocessor connected in our processing units.

NASA / USRA
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

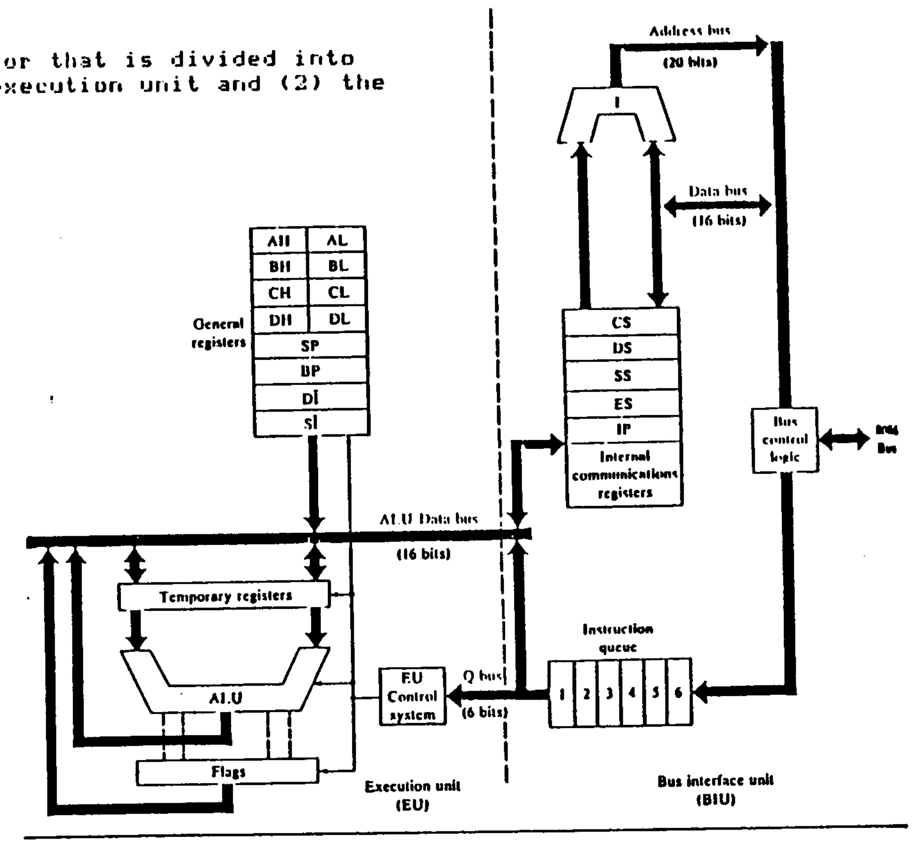
DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUH
PAGE:



Block diagram of typical microprocessor system using bus extenders.

	NASA / USRA **INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B**	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. FOTOUH PAGE:

A 16-bit microprocessor that is divided into two parts: (1) the execution unit and (2) the bus interface unit.



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

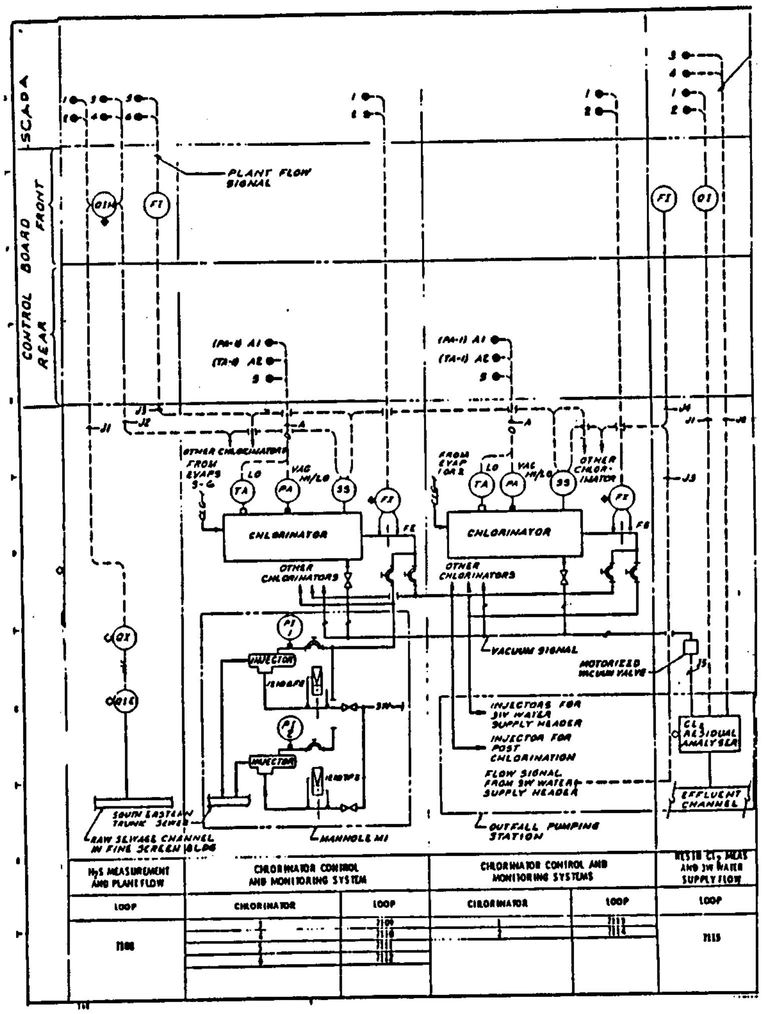
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY



Example of a typical processing plant with alarms controlled by the SCADA.

DEPARTMENT OF CHEMICAL ENGINEERING

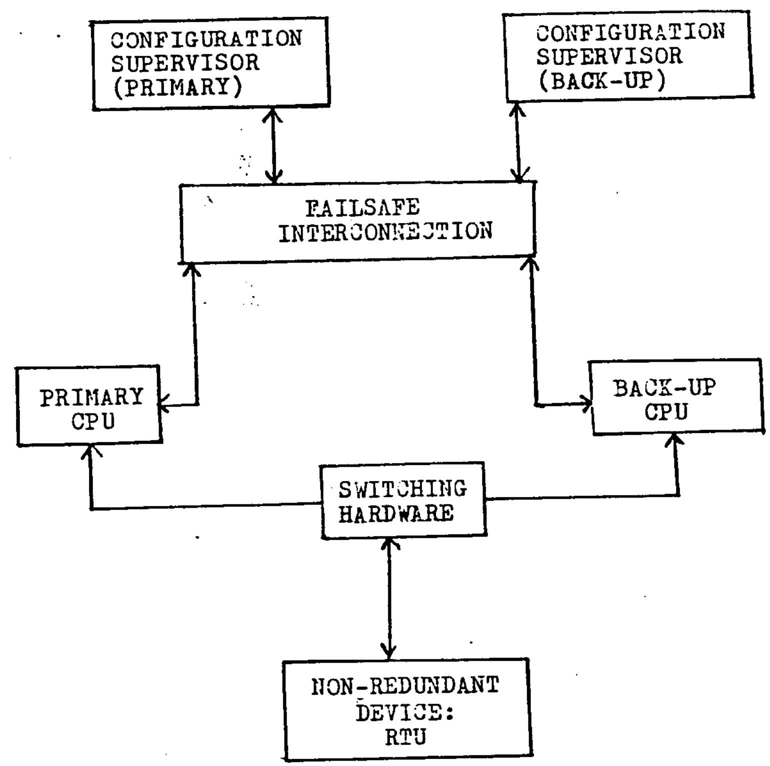
ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

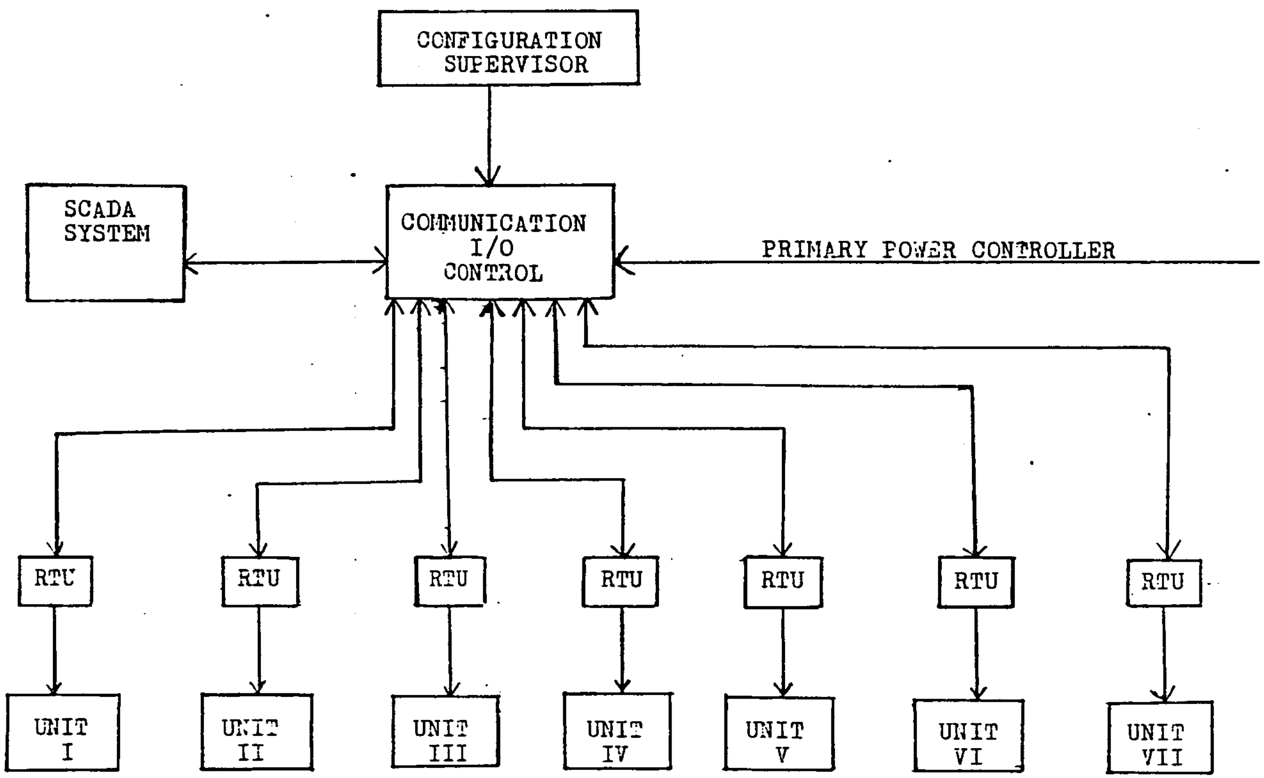


FUNCTIONAL CONFIGURATION SUPERVISOR SYSTEM DIAGRAM

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING	
ADVANCED DESIGN PROJECT	
APPROVED BY: K. FOTOUH	
PAGE:	



SCADA SYSTEM IN COMMUNICATION WITH UNITS

NASA / USRA

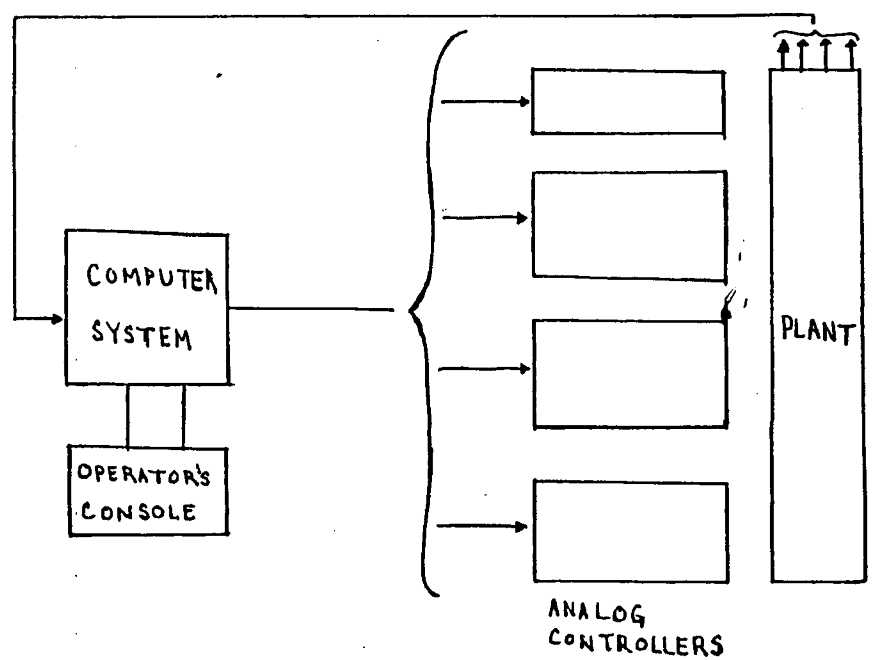
INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:



Supervisory Control System

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

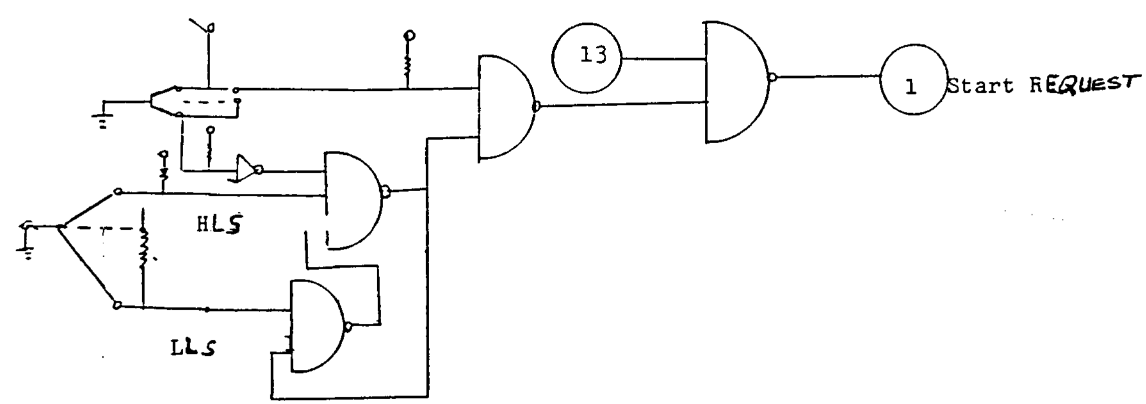
PAGE:

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

ORIGINAL PAGE IS
OF POOR QUALITY

START REQUEST LOGIC CIRCUIT



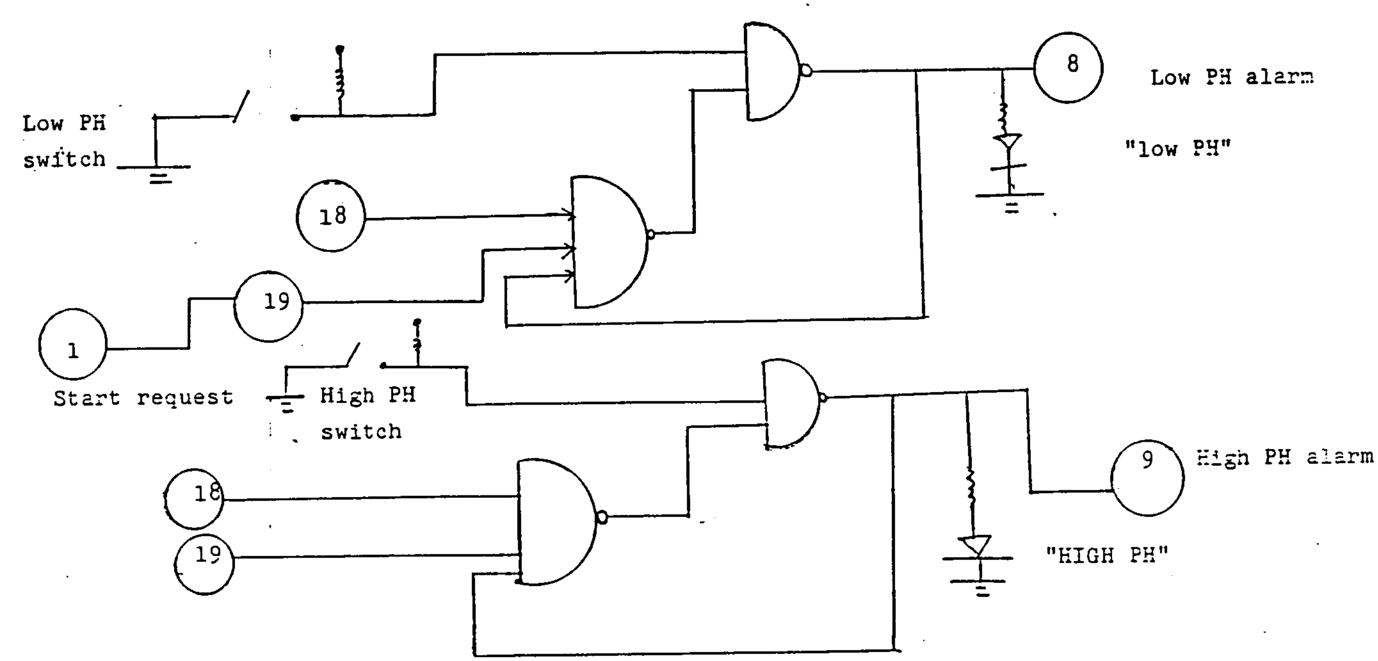
NASA / USRA

INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II - TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING
ADVANCED DESIGN PROJECT
APPROVED BY: K. FOTOUE
PAGE:

ORIGINAL PAGE IS
OF POOR QUALITY

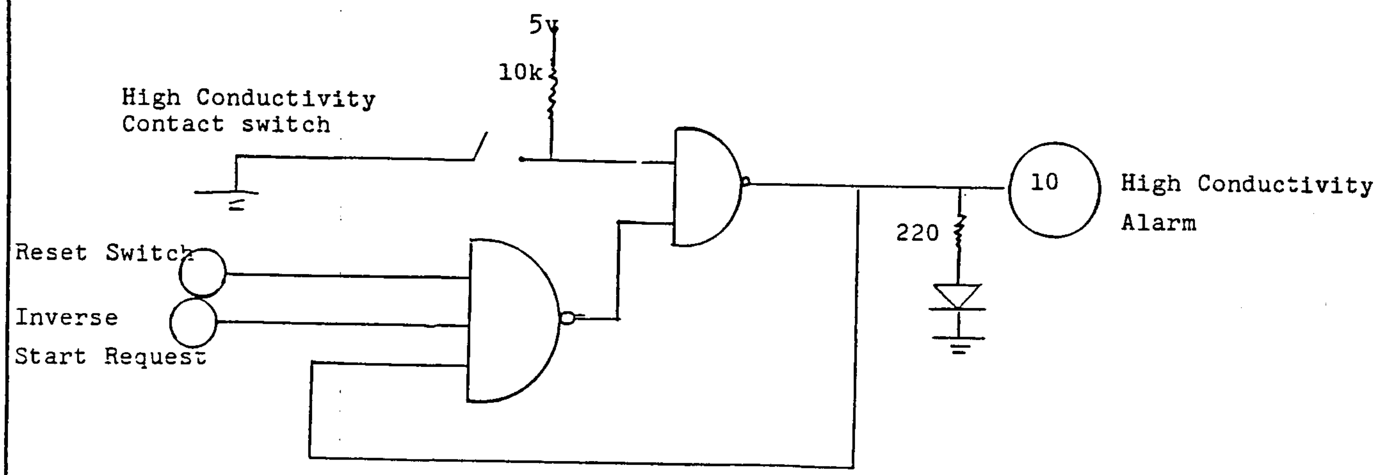
PH ALARMS USING LOGIC CIRCUIT



	NASA / USRA INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B	DEPARTMENT OF CHEMICAL ENGINEERING ADVANCED DESIGN PROJECT APPROVED BY: K. POTOUE PAGE:

ORIGINAL PAGE IS OF POOR QUALITY

CONDUCTIVITY & MOTOR OVERLOAD ALARMS VS LOGIC CIRCUITS



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

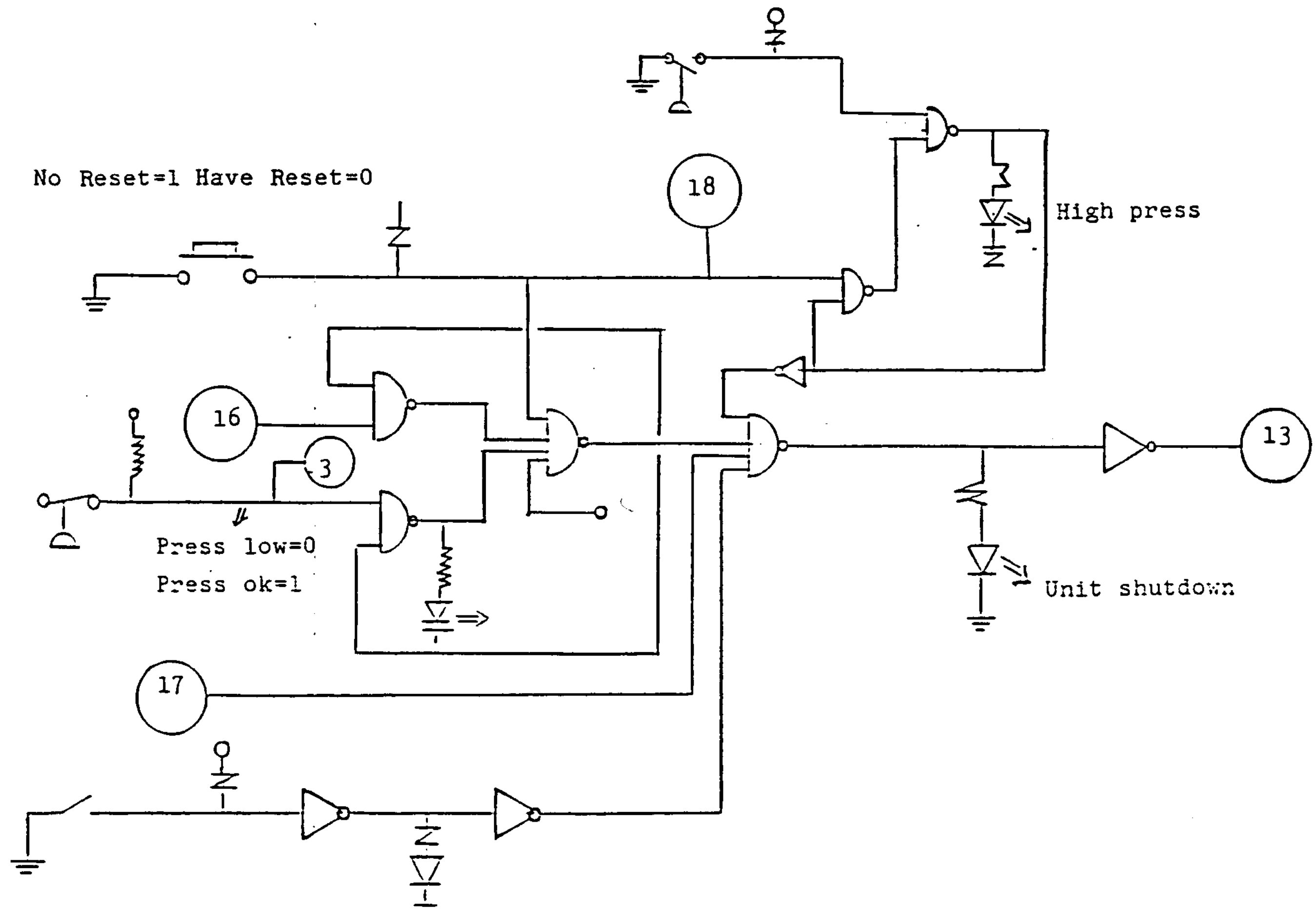
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUE

PAGE:

SHUT-DOWN SYSTEM



NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II - TASK 1-B

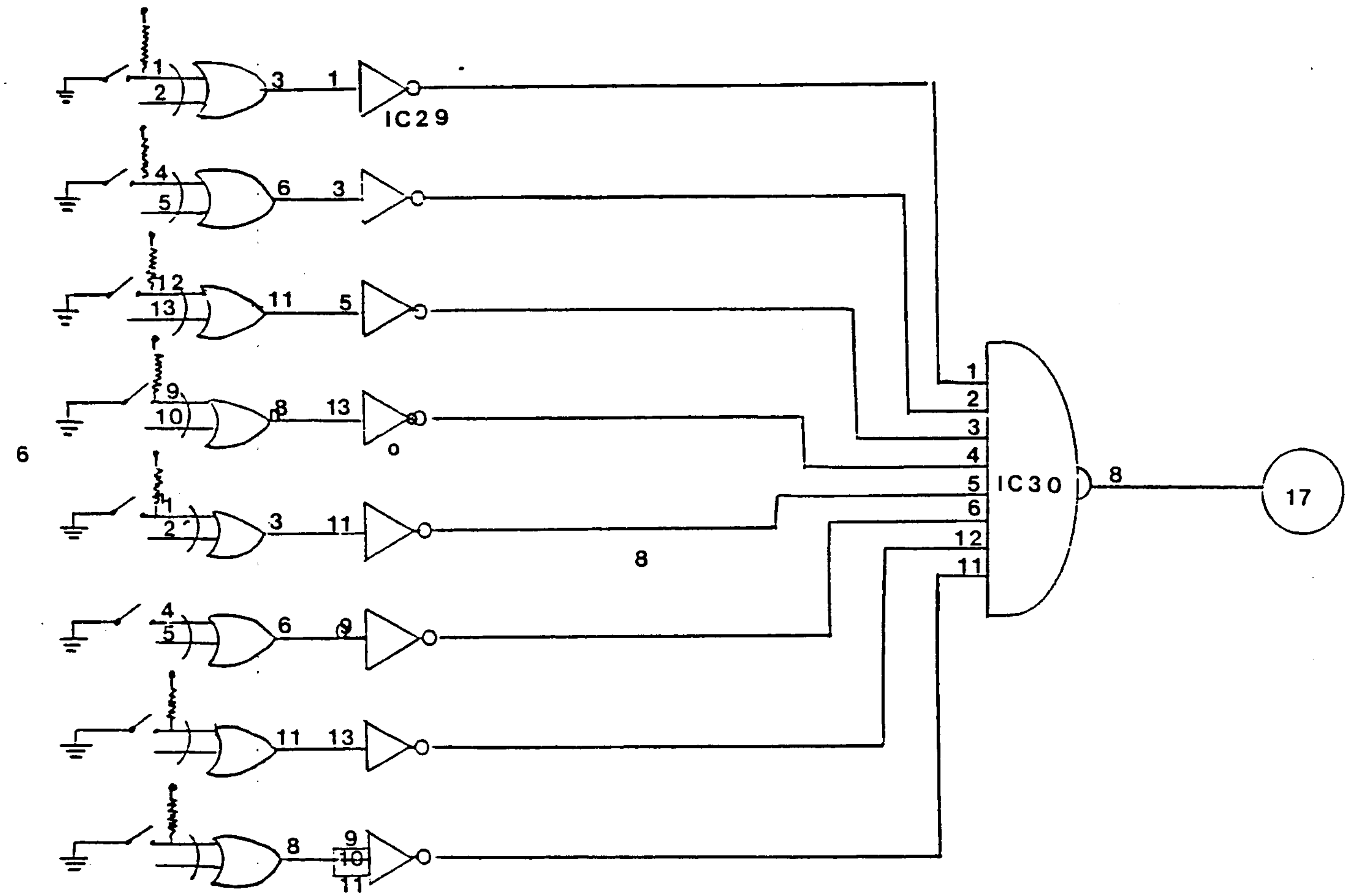
DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUE

PAGE:

SET POINT COMPARING CIRCUIT



NASA / USRA

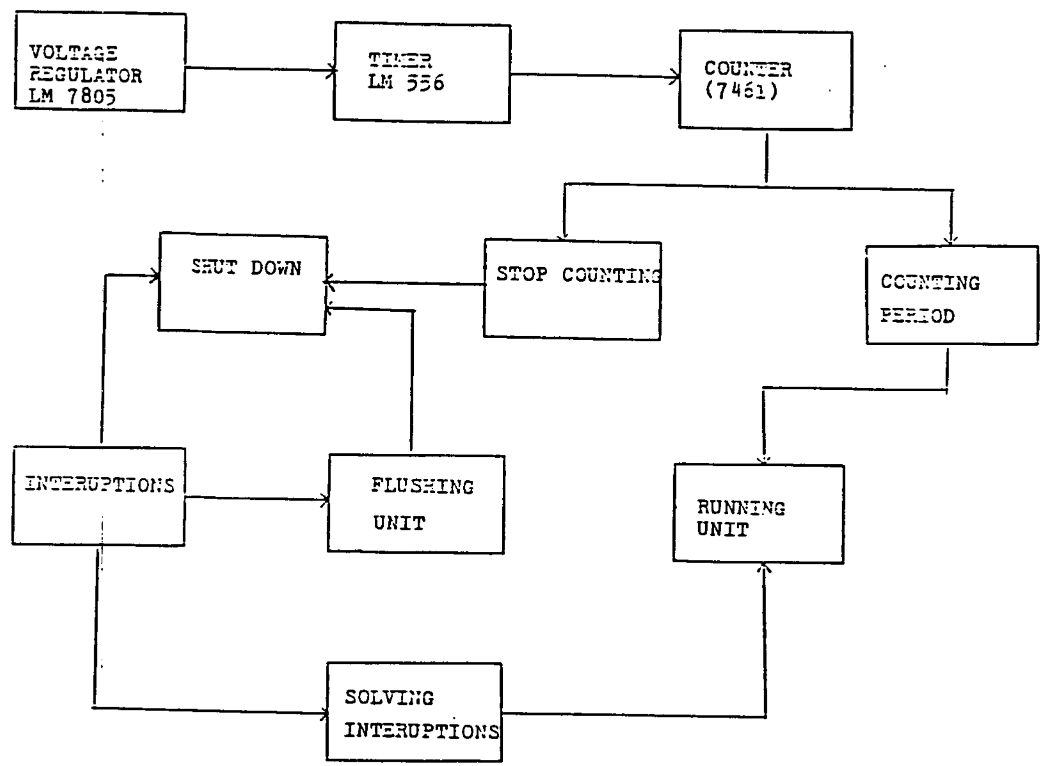
INTEGRATED WATER SYSTEM FOR A
SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE:



BLOCK DIAGRAM OF R.O. UNIT INTEGATED CIRCUIT BOARD

NASA / USRA

INTEGRATED WATER SYSTEM FOR A SPACE COLONY PHASE II-TASK 1-B

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED DESIGN PROJECT

APPROVED BY: K. FOTOUH

PAGE: